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Abstract

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Ph.D.; August 1999

The Pennsylvania State University

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This study examined how manipulating the level of environmental complexity and the type of team training given to subject volunteers impacted important team process behaviors and performance outcomes. Complexity levels were manipulated by directly altering critical target object features and overall planning information ambiguity. This study also examined how subject teams performed in a dynamic environment that not only required cooperative behavior between individuals within a single team, but also collective actions between separate teams to achieve assigned performance goals. This effort focused on testing critical aspects of an emerging framework of multi-team systems (MTSs).

The results from this research initially failed to support the contention that manipulating environmental complexity and team training strongly influenced MTS process behaviors. However, when continuous scores were employed as measures of the MTS's collective training knowledge, analysis revealed that coordination training impacted action process behaviors and thereby indirectly improved performance. These results also provided support for reconceptualizing the relationships existing between central components of the MTS framework. Based on these findings, transition process behaviors provide a critical link between interpersonal and action processes in an MTS. These findings support the emerging theory of MTS and offer some initial clarifications of how these team processes interrelate to enhance overall performance. Prospective directions for future research are suggested.

The Pennsylvania State University

The Graduate School

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THE IMPACT OF ENVIRONMENTAL COMPLEXITY AND TEAM TRAINING ON TEAM PROCESSES AND PERFORMANCE IN MULTI-TEAM ENVIRONMENTS

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by

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We approve the thesis of Marshell G. Cobb.

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Abstract

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Chapter 1

INTRODUCTION

Organizational managers and researchers (e.g., Salas, Dickinson, Converse, & Tannenbaum, 1992; Weaver, Bowers, Salas, & Cannon-Bowers, 1995) have long known that the increasing volume of and reliance on technology in the workplace has significantly contributed to the complexity of the employees' performance environment. This situation has made it virtually impossible for individual employees or institutionalized organizational structures (e.g., departments, units, etc.) to complete their work entirely independent from the actions of other individuals and entities within the organization (Salas et al., 1992; Weaver et al., 1995). In response to technological advances and an increasing emphasis on collective outcomes and products, many organizations have adopted a team approach to the work environment (Brannick, Roach, & Salas, 1993; Cannon-Bowers, Oser, & Flanagan, 1992).

Teams are viewed as more suitable for complex tasks because they allow members to share the workload, monitor work behaviors of other team members, and develop and contribute personal expertise to various subtasks. This increased reliance on teams being responsible for completing complex tasks can easily be seen in many civilian and military contexts. For example, organizations commonly use top management teams to make important decisions impacting the operation and future development of an organization. The military has also applied research on team process and performance to such critical operational areas as tactical decision making (e.g., Cannon-Bowers, Salas, & Baker, 1991), tank crew training (e.g., Cavanagh & Williams, 1987; Tziner & Eden, 1985), aircrew training (e.g., Cavanagh & Williams, 1987; Foushee, 1987) and aircraft command and control (e.g., Elliott, Neville, & Dalrymple, 1996).

Team performance effectiveness has received renewed interest in research and organizational literature due to the pervasive effects of organizational downsizing and technology increasing the levels of complexity and interdependence existing in the workplace (Swezey & Salas, 1992). In response to these developments, leaders and managers frequently turn to teams to effectively deal with the increasingly complex work environment. Cannon-Bowers et al. (1992) asserted that teams are increasingly important in industry because: (1) there are critical organizational tasks which no single individual can accomplish alone, (2) organizational leaders and managers believe that groups perform better than individuals; and (3) group structures have emerged in response to the growing humanistic movement in industry. The increasing importance of teams in the workplace provides a basis for studying teams as separate units of measurement that can and should be differentiated from individual and organizational levels of analysis.

This study examined team performance in contexts that have been largely ignored by much of the empirical research in the area. This study built on the existing body of team research employing low-fidelity personal computer (PC) flight simulations to study team behaviors, team processes, and performance effectiveness (e.g., Goodwin, 1997; Mathieu & Goodwin, 1997; Stout, Cannon-Bowers, Salas, & Morgan, 1990; Kozlowski & Gully, 1996). Specifically, this study explored how manipulating the level of environmental complexity impacted important team process activities and performance outcomes in environments where multiple teams must cooperate to successfully achieve their assigned goals and objectives.

Rather than altering the degree of interdependent activity demanded of subject teams or the ambiguity of task and environmental cues, this study varied the actual level of

complexity existing in the task environment by directly manipulating critical target object features and information ambiguity. Following the recommendations of researchers emphasizing that teams must be studied in more naturalistic decision environments (e.g., Kozlowski & Gully, 1996; Urban, Weaver, Bowers, & Rhodenizer, 1996), this study advanced current team research findings by focusing on team level variables allowing interdependent teams to perform in multi-team environments.

Previous researchers examining team processes and performance have generally manipulated environmental complexity by altering the ambiguity of important information cues associated with higher levels of threat (e.g., Elliott et al., 1996; Hollenbeck et al., 1997) or embedded task events that deviated from previously established routines (e.g., Stout, Salas, & Fowlkes, 1997) or treated complexity as though it was a nearly constant characteristic of the team task environment (e.g., McIntyre & Salas, 1995). The complexity of the environment is an especially important consideration in military combat operations, since the consequences of decision errors due to misidentification of objects in the team's conceptual field can be devastating in terms of international relations, battle outcomes, and loss of lives.

Previous researchers have demonstrated that training is an essential ingredient for any team's success in many different task environments. In their extensive review of team training, Salas, Dickinson, Converse, and Tannenbaum (1992) pointed out that team training has most often emphasized the individual mastery of skills within a team setting. They emphasized that there are many different variables to consider when designing team training programs. They included such variables as the nature of the task, the degree of coordination required of team members, the fidelity of the training environment, and the nature of

performance feedback in their discussion of training designs and taxonomies. They and other researchers (e.g., Funke, 1991; Kaempf, Klein, Thordsen, & Wolf, 1996) have emphasized the importance of examining the effectiveness of various training interventions in differing task environments. To this end, this study also examined how varying the levels of environmental complexity affected subject teams' process behaviors and interacted with multiple team training conditions.

Finally, as mentioned earlier, this study expanded the existing literature by examining how subject teams performed in a dynamic environment that not only required cooperative behavior between individuals within a single team, but also collective actions between separate teams to achieve assigned performance goals. This study contributed to the existing team performance literature by analyzing factors and processes influencing combat aircrew performance under psychologically realistic simulation conditions, task demands, and operational performance standards.

In Chapter 2, I review the existing literature and research examining team process and performance relevant to this study and present the hypotheses tested in this study. In Chapter 3, I discuss the experimental methods and designs used to test these hypotheses. Chapter 4 reviews the team performance and process measures collected for the analysis. The results of the study and analysis are presented in Chapter 5. Chapter 6 provides a discussion of the results and analysis. Finally, Chapter 7 discusses the implications of this study for the field and future research.

Chapter 2

RESEARCH REVIEW

General Theoretical Framework.

Numerous definitions of "teams" exist in the literature (e.g. Brannick et al., 1993; Morgan, Glickman, Woodward, Blaiwes, & Salas, 1986) that focus on different attributes of teams and groups existing in various work environments. I believe Salas, Dickinson, Converse, and Tannenbaum's (1992) definition best describes the distinguishing features of teams commonly found in large organizations, especially operational military units. They defined a team as "...a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span of membership" (p.4). Central to this definition is that effective performance requires a dynamic exchange of information and resources among the team members, coordination of task activities, constant adjustments to task demands, and organizational structuring of team members (Salas et al., 1992).

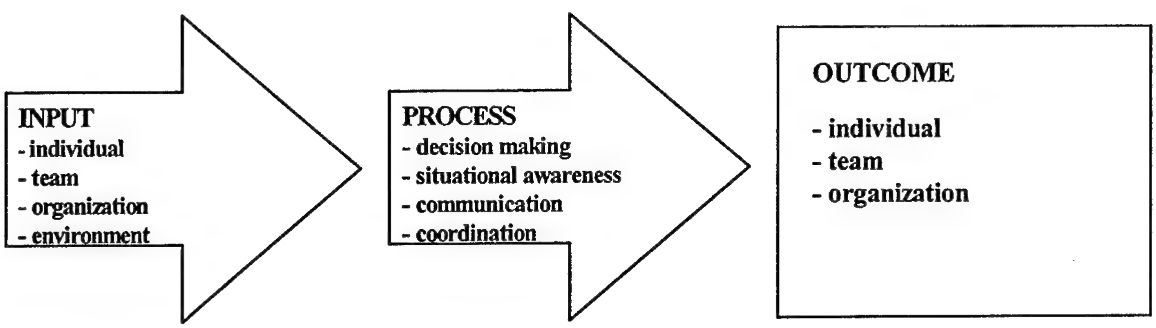
Based on a review of the literature comparing the two classifications (see Hollenbeck et al., 1997; Salas et al., 1992; Tannenbaum, Salas, & Cannon-Bowers, 1996), teams can be distinguished from groups by the fact that all team members have some form of interdependent task responsibilities and share, to some degree, a commonly held perception of the team's purpose and goals. Hollenbeck et al. (1997) pointed out that, unlike many types of groups, team successes and failures have direct consequences for every team member. Based on this literature, I contend that teams represent a more specific configuration of individuals than what are commonly considered to be more loosely defined

groups. Groups tend to come together for much longer periods and have more long-term, general goals than teams. Teams are associated with more specific, focused tasks and objectives and generally exist for a much shorter period of time than groups. Since there is much otherwise insightful research that has treated "groups" (e.g., small group behavior, work group performance, military and civilian aircrews, etc.) and "teams" as equivalent and interchangeable terms, I'll honor the authors' original designations in any direct quotations from specific reports and publications. Otherwise, I'll use the term "teams" in all cases where Salas et al.'s (1992) definition applies.

The I-P-O Framework.

In general, most current research examining team performance and effectiveness has followed Hackman and his colleagues' input-process-outcome (I-P-O) framework, as illustrated in Figure 1 (see Hackman & Oldham, 1980; Hackman, 1992; Heffner, 1996; Guzzo & Dickson, 1996).

Figure 1: Team Process Framework



Inputs include conditions that exist prior to a performance episode, such as team composition (i.e., team member demographics and characteristics), task structures and demands, contextual or situational characteristics, and external organizational factors impacting the nature of the work environment in which teams find themselves (Salas et al., 1992). Performance episodes are "distinguishable periods of time over which performance

accrues and is reviewed" (Mathieu & Button, 1992, p. 1759). Heffner (1996) pointed out that training is an important precursor to the inputs of the first performance episode and provides teams with a basis for understanding and interpreting their performance inputs. An inherent assumption in the I-P-O model is that there are separate inputs, processes, and outcomes for each performance episode. Hackman (1992) pointed out that individual members of a team also provide additional, important contextual cues and inputs for each member's behavior within the team.

One could take Hackman's (1992) perspective a step further by also asserting that teams working together or separately in the same environment significantly influence each other's performance and behavior (Swezey & Salas, 1992). Teams rarely operate totally on their own, independent of the actions of other teams and individuals. Even teams working on their own depend on others for support to achieve their assigned objectives. In many situations, action teams are comprised of smaller teams working collectively toward some specified goal. An example of this type of team can be seen in many military settings. A typical fighter aircraft crew is comprised of two individuals working together. Yet, single aircraft are almost never used in isolation in combat environments to achieve significant mission goals or objectives. Multiple flight teams are brought together and must work in concert with each other to achieve their mission objectives and goals. Even in business, process action teams usually comprise multiple teams working together and sharing resources and task responsibilities to reach a common goal (see Peters, 1994). Teams almost always operate in multi-team environments, yet there seems to have been very little attention paid to this aspect of the team performance environment.

In their review of networked computer simulations designed to explore team performance, Weaver et al. (1995) noted that teams are frequently hierarchical and have varying degrees of responsibilities and expertise among their members. These factors influence team member behaviors and performance by creating preconceived expectations about decision making, power relationships, role responsibilities, and communication flow within the team (see Salas et al., 1992; Weaver et al, 1995).

This is especially true in military organizations where the rank, denoting an individual's level of authority and position within the organization, and experience level of individual crew members may be very different within the same team. A Second Lieutenant, fresh out of college and technical training school, could be suddenly put in charge of a crew directing Master Sergeants with nearly twenty years of task experience.[1] A junior officer could also find himself/herself acting as the mission commander for an air strike against enemy targets, even though more senior officers are present within the strike team. In deciding whom to place in a leadership position for a tactical (i.e., battlefield or combat) military operation, technical expertise and recent operational experience are often more important than the discrepancy between an individual's rank and that of other team members. This type of distributed composition requires a team to establish a balance between official positions of authority and sources of task expertise critical to achieving mission requirements and desired performance outcomes.

Process factors describe how team members interact and collectively deal with their environment. They include variables such as communication, cooperation, coordination, cohesion, leadership, and decision making (cf., Cobb, 1998; Foushee, 1987; Heffner, 1996; Salas et al., 1992; Stout et al., 1997; Tziner & Eden, 1985). Process mediates a team's

effectiveness in creating desired outcomes from various inputs. Even under optimal environmental conditions, poor team process can lead to process loss (Steiner, 1972) that results in less than optimal performance. Conversely, in suboptimal operating conditions, good team process behaviors may enable a higher team performance outcome than might be expected considering the constraints existing in the situation.

Researchers interested in examining team process variables are immediately confronted with a significant conceptual problem. As Cannon-Bowers, Tannenbaum, Salas, and Volpe (1995) pointed out, there are numerous inconsistencies in the manner previous researchers have labeled, defined, and operationalized many of the variables identified as composing team process. These inconsistencies potentially represent significant hurdles to understanding the results or previous studies, providing the conceptual foundation needed to compare the results of various empirical studies, and generalizing research findings to more applied settings. In response to these problems, researchers have relied on carefully defined and bounded taxonomies to conceptualize their hypotheses and results.

Fleishman and Zaccaro (1992) and Brannick and his colleagues (Brannick et al., 1993; Prince, Brannick, Prince, & Salas, 1997) have created team process taxonomies that have provided a common conceptual foundation for many team research efforts. Fleishman and Zaccaro's (1992) taxonomy attempted to classify various task performance functions. Their taxonomy includes several dimensions (i.e., team orientation, resource distribution, timing, response coordination, motivation, systems monitoring, and procedural maintenance) describing "a set of responses, independent and synchronized, that is separate from the task itself" (Fleishman & Zaccaro, 1992, p. 34). Although it appears that Fleishman and Zaccaro successfully identified the task-related and coordination variables necessary for high

performance teams, their dimensions have been criticized as too specific to adequately capture the varied interactions occurring between team members performing their tasks (see Heffner, 1996).

A second taxonomy was developed and empirically tested by Brannick and his colleagues (Brannick et al., 1996; Prince et al., 1997). Like Fleishman and Zaccaro's (1992) concept, Brannick's taxonomy also identified six dimensions composing what is generally considered team process. These dimensions included leadership, assertiveness, decision making/mission analysis, adaptability/flexibility, situational awareness, and communication. Unlike the previous taxonomies, these dimensions were specifically focused on specific types of team member behaviors. While a step forward in many regards, especially in directing attention to team member actions and behaviors, Brannick's taxonomy repeats one conceptual labeling error found in previous systems. It could be argued that many of the dimensions Brannick specified are actually better seen as emerging team or team member characteristics than actual team processes.

Process implies that something is acted upon to achieve some defined result. Leadership, assertiveness, situational awareness, and other labels seem to define states or categories of team member behavior rather than the actual behaviors enacted by team members, jointly or individually, to convert various team inputs to desired team outcomes. In their description and examination of teamwork competencies essential to effective team performance, Cannon-Bowers et al. (1995) added performance monitoring and feedback, and interpersonal skills to Brannick's six dimensions. While the added dimensions were certainly more descriptive of process related behaviors, the resulting taxonomy seemed too limited to comprehensively capture the underlying nature of team processes.

In an effort to better conceptualize team process variables, Marks, Mathieu, & Zaccaro (in preparation) have created a synthesis of existing process taxonomies that focuses on the dynamic performance environment found in military settings. In their proposed taxonomy, team process comprises transition processes, action processes, and interpersonal processes. According to this framework, experimenters should closely examine the process behaviors that teams employ to convert situational inputs into viable and desired outputs. This should lead to more accurate and descriptive conclusions than attempting to apply more individually defined constructs and behavior categorizations to team interactions and behaviors.

Generally speaking, *transition processes* can be seen as those behaviors and actions teams enact before actually performing their assigned tasks. Once brought together to perform a task, teams and individual team members must spend some time to gain an understanding of their situation, the tasks, and the resources they have available to them, including team member expertise. Each of these behaviors are directed at employing current inputs to arrive at decisions and conclusions affecting future actions. This differs from more retrospective sensemaking behaviors (c.g., Weick, 1995) in that individuals are less concerned about making sense of events relative to themselves and their sense of identity than they are in deciding how to use inputs to achieve specified task goals. Based on previous research findings, transition process behaviors have been further conceptualized as mission analysis, goal specification, and strategy formation (Marks et al., in preparation).

Mission analysis requires team members to interpret and evaluate the team's assigned tasks or mission. This includes teams identifying the mission's main tasks as well as the operative environmental conditions and team resources available for mission execution.

During goal specification, teams jointly identify and prioritize their goals and subgoals for accomplishing their overall task or mission. Teams engage in strategy planning to formulate their plans and courses of actions needed to accomplish their mission goals. According to Marks et al., this planning includes: (1) making a primary or generic plan, (2) exploring and anticipating how to react to the most probable contingencies that could occur during the mission, and (3) setting the foundation for making additional changes to all previous plans in response to unexpected changes in the situation during the mission (i.e., reactive strategic planning).

Action processes include those team member behaviors exhibited while the team is carrying our their planned actions and accomplishing performance tasks. According to Marks et al., these processes include monitoring progress toward goals, systems monitoring (i.e., monitoring internal technology systems and the external environmental for changes and task cues), team monitoring and backup behavior, coordination activities, and communications between team members. These are very similar to the teamwork KSAs described by earlier researchers (cf., Cannon-Bowers et al., 1995).

Finally, *Interpersonal processes*, as described by earlier researchers (see McIntyre & Salas, 1995; Pelled, 1996; Prince et al., 1997), include those affect driven behaviors associated with reducing interpersonal conflict and keeping team members motivated (Marks et al., in preparation). Teams that demonstrate an increased awareness of potential areas of interpersonal conflict and stereotyping and understand how these factors can impact overall team performance are more effective performers, regardless of specific assigned tasks (Pelled, 1996).

Although focused on the type of dynamic task environments found in military settings, Marks et al. emphasized that their taxonomy capitalizes upon previous research findings and can be generalized to many other task environments. They asserted that the restructuring of previously supported taxonomies into a framework that better represents the underlying processes operating in a team environment provides a stronger foundation for future research and performance assessments. They also emphasized that their framework comprises processes and behaviors that can be assessed at both the individual (i.e., within teams) and team (i.e., between teams) levels of measurement. This enhances researchers' ability to conduct multilevel assessments of team performance and potentially generalize their results to various work environments.

Outcomes are the products of team activity that are valued by either the organization or team members. These outcomes characterize the effectiveness of the team and generally focus on the quality, quantity, and timeliness of the products the team produces (Heffner, 1996). With the exception of the initial formation of the team, the outcomes from one performance episode will also influence the inputs of the next performance episode. In a dynamic environment, such as air combat operations, teams are normally required to produce multiple, simultaneous outcomes.

Team members are also often required to simultaneously perform individual tasks while fulfilling team responsibilities. For example, pilots and weapons officers flying combat aircraft are directly responsible for simultaneously identifying and tracking many different types of aircraft and ground vehicles, while ensuring the team fulfills mission objectives established by senior commanders. In combat environments, a relatively high quantity of decision outcomes must also be high in quality to prevent or minimize losses

among friendly forces. As well publicized in the public media, a mistake in identifying friend from foe can have disastrous consequences for the team, a battle, and sometimes the overall war effort.

Based on this theoretical foundation and previous research empirically employing variations of the I-P-O framework, I hypothesized that each type of team process, i.e. transition, action, and interpersonal, would directly impact how well teams perform the task they are presented. Based on existing research, the link between interpersonal processes and effective team performance may be weakest and include some contradictory findings (see Driskell & Salas, 1992). However, there is also substantial evidence indicating that interpersonal interactions play an important role in planning and carrying out task strategies (see Pelled, 1996; Prince et al., 1997). Based on the framework and taxonomy proposed by Marks et al. (in preparation), I hypothesized that:

Hypothesis 1: Higher levels of transition process behaviors will be associated with higher levels of multi-team system (MTS) performance.

Hypothesis 2: Higher levels of action process behaviors will be associated with higher levels of MTS performance.

Hypothesis 3: Higher levels of interpersonal process behaviors will be associated with higher levels of MTS performance.

To test these hypotheses, this study placed subjects in one of two dyads, representing operational combat aircrews comprising pilot and weapons specialist positions. These positions and two-person teams were jointly responsible for achieving assigned mission objectives in three simulated air-to-ground combat missions.[2] In this way, team members were interdependent within their assigned dyad as well as within the larger two dyad team,

referred to as a multi-team system (MTS). Based on Marks et al.'s (in preparation) discussion, this two dyad structure is the minimum unit possible in a MTS. This setting not only lent itself to advancing the existing literature on team process and performance in a multi-team environment, but it also presented an excellent opportunity to examine team performance variables and behaviors in terms of Marks et al.'s taxonomy.

One consideration for the hypotheses tested in this study was the implied ordering of and relationships between the three types of team processes described by Marks et al. (in preparation). Given my previous description of these constructs, it seemed reasonable to conclude that transition processes should occur, or at least be sampled and measured, before teams attempt to carry out their plans, i.e. action processes, or resolve and manage interpersonal conflict during the execution of their actions, i.e. interpersonal processes. Based on the general design of the experimental task, i.e. planning and carrying out a simulated military combat mission, teams would normally meet and jointly plan their actions and activities to achieve their assigned objectives, i.e. their mission strategy, before carrying out any actions in the simulation. While it is certainly reasonable to assume that teams would engage in interpersonal processes during these planning sessions, I decided to focus on how the effectiveness of the teams' transition processes impacted not only the teams' desired outcomes (i.e. hypothesis 1) but also their action and interpersonal processes. Based on previous research and personal military planning and training experience, I hypothesized that:

Hypothesis 4: Higher levels of transition process behaviors will result in increased levels of effective team action process behaviors.

Hypothesis 5: Higher levels of transition process behaviors will result in increased levels of effective team interpersonal process behaviors.

Team Effectiveness reflects how well a team accomplishes its purpose or mission (Tannenbaum, Salas, & Cannon-Bowers, 1996; Wiener, Kanki, & Helmreich, 1993). Although, as illustrated by the many variations described in the literature, effectiveness can be quantified differently for almost every type of team or context, almost all of the variations are concerned with evaluations of a team's collective performance. Research and organizational assessments have routinely focused on the quantity and quality of the services and products provided by teams. Aggregating the outputs of individual team members or relying on an archival, objective scoring algorithm frequently define team outcomes (see Cobb, 1998; Elliott et al., 1996; Tesluk, Mathieu, Zaccaro, & Marks, 1997). For example, the most common performance measure in many military related simulations is a final performance score, usually based on the number of friendly forces surviving and the number of enemy destroyed during the simulation (e.g., Cobb, 1998; Elliott et al., 1996; Elliott, Neville, Dalrymple, & Tower, 1997). In some cases, reliance on such scoring mechanisms may present an incomplete or inaccurate picture of the team's overall performance.

There is little information in objective, automated composite scores to discern how teams are able to overcome unexpected changes in the situation or how effectively they prioritized and completed their assigned tasks. Destroying "enemy" targets and saving "friendly" forces, the most prevalent factors in such scoring algorithms, are important criteria, but they are not always the most productive outcomes when collective actions are required (see Cobb, 1998). Not everyone on a team, or every team within a larger grouping

or team, can seek to maximize their individual performance score without undermining the team's ability to achieve its overall goals.

Often, especially in military contexts, such egocentric behavior is extremely counterproductive and dangerous to overall mission objectives and even the welfare of other assets or teams working in the same environment (i.e., joint operations, joint ventures, research and development). When individuals or teams pursue their own goals, while ignoring those associated with the larger collective interest, resources become depleted, strategies are undermined, and uncertainty increases since others can no longer predict their behavior and actions. Tannenbaum et al. (1996) included a team's ability to overcome uncertainty, "to remain vital and alive and to grow and regenerate itself," in their view of team effectiveness (p.505). They emphasized that a team's ability to overcome uncertainty enables a team to sustain its performance and fulfill its purpose over a period of time despite increasingly complex task environments.

Environmental Complexity.

The stability and nature of the task environment a team operates within are important contextual factors impacting performance (see Guzzo, 1995; Hackman & Morris, 1975; Salas et al., 1992). Based on his review of current research, Guzzo asserted that context is the primary driver of team effectiveness (see Guzzo, 1995; Guzzo & Dickson, 1996). Tasks vary in the type and amount of interdependence and contextual information required to successfully complete them (see Argote & McGrath, 1993; Straus & McGrath, 1994). The greater the need for team members to depend on and directly support one another to accomplish tasks, the more complex their interdependence and environment will be (Saavedra, Earley, & Van Dyne, 1993).

Interdependency can also be looked at as the interconnections among group member tasks (see Van de Ven & Ferry, 1980). If a specific team member has all the resources, information, authority, and means needed to make and carry out a decision, she/he has little reason to interact with other team members. This person's task is greatly simplified, since time and cognitive resources do not have to be devoted to ensuring a teammate understands the situation, agrees to the intended response, and provides the resources or assistance needed to fulfill the task. Research has consistently emphasized the importance of carefully considering the integration of individual contributions and collective coordination when examining team and group behaviors (see Zaccaro, Blair, Peterson, & Zazanis, 1995).

Using low-fidelity computer simulations and two-person teams of undergraduate students, Stout, Salas, and Carson (1994) examined how team processes and communications were impacted by task complexity. They found when team members are required to act interdependently, behaviors such as providing information before it is needed, planning, asking for input, and intervening to help teammates become increasingly important to effective task performance. There has been a significant amount of research indicating that task interdependence affects many different areas of group and team performance (Saavedra et al., 1993; Shea & Guzzo, 1987), as well as such key team processes as cooperation between group members and interpersonal communication and interactions between team members (Kelley & McGrath, 1985).

In their study of task strategies and intergroup conflict, Saavedra et al. (1993) proposed a three-dimensional construct, *complex interdependence*, to capture the interactions between task interdependence, goals, and feedback. These attributes of complex interdependence corresponded to the extent: (a) group members must rely on each other to

perform tasks, (b) individual or group performance objectives are provided (goals), and (c) performance feedback is provided for individual members or the entire group (feedback) (Saavedra et al., 1993). Based on earlier research (see Thompson, 1967), they proposed that there exists a hierarchy of group member interactions that reflects increasing levels of dependence and coordination needs. At the lowest level, pooled interdependence requires no direct interaction between individuals as group members fulfill similar roles. While each individual contributes to the overall performance of the group, group members complete assigned tasks largely without regard for the work of others.

The next level, according to Saavedra et al. (1993), is sequential interdependence. At this level, one group member's output requires the input of another in a sequential fashion. Group members occupy different roles and perform different tasks in a prescribed order. At the next higher level, reciprocal interdependence, one person's output also becomes another's input, but the order is flexible. Group performance requires coordination of differing roles and specialties among its members. Finally, team interdependence forces group members to jointly problem solve and collaborate to complete tasks. This requires interaction to determine the particular course of inputs and outputs among members and usually involve an exchange of resources, information, or ideas (Saavedra et al., 1993; Tesluk et al., 1997).

While there has been considerable research that has focused on the level of interdependence required by or demonstrated by team activities, there has actually been very little research that has sought to directly vary the complexity of the interdependent tasks themselves. According to Kluger and DeNisi (1996), complexity reflects the number of actions, dependencies among actions, and the temporal dependencies needed for successful task performance. Complexity is best considered as a task characteristic independent of the

attributes of the participants performing it (Wood, 1986). In this perspective, complexity arises directly from the nature of the task and the task environment, not from the attributes or interactions of the individuals accomplishing the task. It is only when the actions of an individual, or team in the context of this proposal, alters the nature of the task or the physical environment in such a way as to change the acts required to accomplish the task that individuals contribute to the complexity of the situation. In his classic examination of the construct, Wood (1986) describes three types of complexity: component, coordinate, and dynamic.

Component complexity is concerned with the number of distinct, nonredundant acts that must be executed to perform the task. Component complexity is also concerned with how many information cues must be processed when performing the activity (Wood, 1986). As can be seen in research examining situational awareness (see Endsley, 1995; Goodwin, 1997), work environments differ greatly in the specific features a team must attend to in order to succeed. The ability to detect and distinguish the presence or absence of various environmental cues is an important consideration in decision making behaviors. The greater the combination of object features to which a subject, an individual or team, must attend, the more difficult the decision task (Kaempf et al., 1996; Triesman, 1991).

Kaempf et al. (1996) found that 95% of their subjects used recognition strategies when choosing decision options in complex, time constrained situations. Their subjects relied on feature-matching and story generation strategies to build and maintain their situational awareness. As many other researchers had discovered (see Meller, Schwartz, & Cooke, 1998; Oaksford & Chater, 1994; Tversky & Kahneman, 1982), Kaempf et al. described how their subjects relied on heuristics and satisficing (i.e., selecting the first

adequate solution) techniques to reduce their cognitive workload and deal effectively with the complexity of their decision tasks.

From a military standpoint, one of the goals of training is to ensure that individuals are capable of distinguishing friendly from enemy forces. In the past, military members were trained to recognize key features that distinguished one weapon design from another. This feature-based strategy was effective as long as potentially competing nations employed differing weapons designs. In his study of problem-solving behavior among commercial pilots, Casner (1994) found that pilots relied heavily on feature-matching strategies when reacting to air traffic controller inputs. Similar results were found by Kaempf et al. (1996) in their observations of decision processes on US Navy AEGIS cruisers. Due to the increased presence of similar, if not identical, military hardware throughout the world, matching features to designs and using these matches to determine their nationality has become an increasingly difficult task in the modern battlefield. In essence, increased similarity, if not complete redundancy due to reverse engineering or international weapons trade, between the weapons used by competing nations has undermined previous training based on identifying and matching specific design features.

Wood (1986) also identified two other types of complexity. Coordinative complexity focuses on the timing or sequencing, frequency, intensity, and location required to perform required acts. The more complex the relationships between these attributes, the greater the knowledge and skill an individual must have to accomplish the task. Dynamic complexity is created by changes in the environment that impact the relationship between task inputs and task products. Since performance in such complex environments requires knowledge about changes over time, it might be easier to equate this type of complexity with the

predictiveness of the environment. Lower levels of dynamic complexity are characterized by stable, predictable environments. Higher levels of complexity exist when unexpected changes alter the performance environment and the relationships between task inputs and products.

The ability to identify and remain cognizant of changes in the environment and relevant task demands, i.e. situational awareness, is a critical performance component of highly dynamic and complex tasks (Goodwin, 1997; Wellens, 1993). Situational awareness includes perceiving current environmental elements in both time and space, comprehending the meaning and significance of these elements, and predicting probable actions of these elements in the immediate future (Endsley, 1995). Research and experience have repeatedly shown that situational awareness is fundamental to successful team performance in military, organizational, and industrial settings. Kozlowski & Gully (1996) estimated that 80 percent of aircraft accidents, as well as tragic events like the destruction of a civilian airliner by the USS Vincennes in the Persian Gulf, are attributable to errors made by highly trained, experienced specialists operating in a team context. Official investigators and academic researchers have tracked many of these errors to a breakdown in a team's ability to recognize and adapt to unexpected changes in the environment.

Although it has been frequently studied by military researchers in terms of aircraft cockpit designs and head-up displays (e.g., Goodwin, 1997; Stinnet, 1989), situational awareness has gained in importance when studying team process. For example, enhancing individual and collective situational awareness has become increasingly significant in pilot and aircrew training programs (Shrestha, Prince, Baker, & Salas, 1995). Yet, as Mathieu, Goodwin, Heffner, and Born (1996) pointed out, there has been relatively limited research

focusing on the role of contextual influences on team processes. While some researchers have emphasized the importance of accounting for the impact of organizational context or environment on team effectiveness (see Gladstein, 1984; Salas et al., 1992), Mathieu et al. noted that even among the few studies empirically examining this issue, teams are seen as largely passive respondents to situational demands.

Following Ancona and her colleagues' research indicating that teams are affected by and, in turn, affect their environment (Ancona & Caldwell, 1988, 1992), Mathieu et al. (1996) examined the hypothesis that team processes and environmental demands co-evolve over time. They determined that as teams choose task strategies and execute decisions in response to diverse situational demands, their actions alter the resources available for future actions and, to some degree, the environment surrounding them. For example, an Airborne Warning and Control Systems (AWACS) crew vectoring friendly resources to respond to an enemy threat not only changes the friendly resources available for future responses, but the success or failure of their decision also impacts possible reactions by the adversary. Thus, an action-reaction cycle begins that directly impacts the potential complexity of future situations and the very nature of any further threat options.

From this discussion, one would expect teams to have more difficulty effectively performing in complex situations than in more routine, normal conditions. By their nature, complex situations place more task demands upon individuals and teams and require higher levels of problem solving than more routine conditions (cf., Funke, 1991; Kaempf et al., 1996; Orasanu, 1993). Based on the existing literature (cf., Cobb, 1998; Elliott et al., 1996; Goodwin 1997; Guzzo & Dickson, 1996), I expect higher levels of complexity to negatively impact MTS performance.

Hypothesis 6: Increased levels of environmental complexity will have a direct negative impact on teams' performance in multi-team environments.

The situation can become even more convoluted, when one considers the fact that the AWACS crew mentioned previously is only one of many teams operating in the environment with the capability to direct and redirect combat resources. The combat forces, themselves, are also comprised of teams highly skilled in the application of force in each of the combat environments, i.e. land, air, and sea. All of these combat and control teams must be carefully integrated into a comprehensive plan that orchestrates their actions within a larger context to achieve mission goals and command objectives. While the actions of individual aircrews and combat units are important, it's the performance of the larger "team of teams" that ultimately determines the success or failure of the overall mission. During training, individuals not only learn about their individual responsibilities on their specific aircrew or combat unit, but they are also trained to understand how their team fits into larger combined forces – in essence, mission teams. These training experiences are thought to provide the task and teamwork KSAs needed to function and succeed in increasingly complex environments.

Team Training.

Kozlowski and Gully (1996) asserted that most training programs are based on making the right decision to achieve some specified outcome. They challenged this notion by emphasizing that rational analysis does not always '… yield optimal solutions when the problem is ill-defined, information is ambiguous, and the situation is dynamic" (p.4). Their focus was on assessing the appropriateness of the team's overall decision process, i.e. making the decision in the right way. Although they concentrated on the adaptive expertise of teams

from a learning perspective, Kozlowski and Gully made a very valid point. Real world situations and problems rarely fit rational models of outcome-based decision models.

While a strength of their research was in linking active learning processes with adaptive expertise, Kozlowski and Gully (1996), as well as other researchers, still seemed to ignore how team decisions can radically change their environmental context. To put it another way, environments are not only dynamic and fluid, but they are also continually evolving. Training teams for such dynamic environments requires team members to master situationally relevant knowledge, skills, and attitudes (KSAs), as well as developing more general skills that can be transferred to other task environments and team settings (Cannon-Bowers et al., 1995).

Crew resource management (CRM) training is specifically designed to enhance the effectiveness of aviation crews' team process by improving communication, coordination, and situational awareness (Cavanagh & Williams, 1987; Guzzo & Dickson, 1996).[3] This type of training is not intended to strengthen any particular team. Rather, CRM seeks to make individuals more effective in team settings by emphasizing team process strategies and behaviors. Recognizing the broad scope and variety of training activities involved in civilian and military CRM programs, Bowers, Morgan, Salas, and Prince (1993) described how aircrew coordination training (ACT) focuses on training interventions specifically designed to improve coordination behaviors required for successful flight operations. This type of CRM training has been especially embraced by the U.S. Navy to improve the quality and effectiveness of undergraduate pilot and aircrew training.

In essence, CRM training and ACT focus on developing behaviors and KSAs directly relevant to aircrew coordination and communication under many different task conditions

(see Prince & Salas, 1993). These programs are concerned with team members mastering what Cannon-Bowers et al. (1995) called generic team competencies. Contrary to skills and knowledge required to effectively function as a member of one specific team, these generic competencies should be applicable to virtually any team setting or composition (Cannon-Bowers et al., 1995). Given the transitory nature of aircrew membership in civilian and military settings, identifying and emphasizing transferable team process skills is an important aspect of CRM and other forms of team training.

Due to manning limitations and scheduling demands, it has been common practice for most military teams, especially combat teams and aircrews, to frequently alter their membership over time. As in commercial industries and airlines, some teams may only be brought together for a single task or mission. Once that is accomplished, the individuals return to their original units or departments. In some military situations, especially during long deployments and combat engagements, team membership may change many times in a relatively short time during the duration of the mission deployment.

Researchers (e.g., Leedom & Simon, 1995) have shown that frequently altering air crew membership may actually minimize the number of performance errors committed by crews due to complacency and overconfidence. Leedom and Simon (1995) found that established military practices emphasizing flexible crew pairings, rather than fixed, long-term crew pairings (i.e., battle rostering), actually seem to enhance team performance. They also determined that behavior-based coordination training resulted in significantly more effective team performance and fewer mission errors than reliance on team member familiarity or more attitudinal based training interventions.

Regardless of the timing of the change or the duration of membership, military commanders and organizational managers fully expect individuals to clearly understand his/her role and position within the team. New team members are expected to be completely capable of not only carrying out their assigned tasks, but also of smoothly interacting with other members of the team on an interpersonal basis. Such a perspective relies heavily on training programs to teach individuals how to integrate taskwork and teamwork skills (Salas et al., 1992).

According to Cannon-Bowers et al. (1995), taskwork skills include those KSAs needed to apply these task competencies to execute assigned tasks and responsibilities. These include cue-strategy associations and understanding team member roles and responsibilities. Teamwork KSAs enable team members to actually carry out required functions and tasks. These competencies include such behaviors as situational awareness, performance monitoring and feedback, coordination, and communication (Cannon-Bowers et al., 1995).

Similar to the taxonomy suggested by Cannon-Bowers et al. (1995) that emphasized task and team competencies, Salas et al. (1992) asserted that embedding important task information within relevant teamwork skills may be an effective training approach. Marks et al. (1997) presented subjects with essential task elements accompanied by structures of team interaction. Teams were provided information about the relationships between components, including role structures associated with individual functions, and the relationships between role structures. They found a significant relationship between teamwork training and team effectiveness.

Based on their extensive review of CRM research, critical incidents interviews with over 200 military cockpit crew members, and analysis of 225 aviation mishaps, Prince and her colleagues concluded that seven skills appeared to be particularly critical to effective team process and performance (Prince et al., 1997; Prince and Salas, 1993). They identified the following skill dimensions as especially critical to aviation teams: (1) communication, (2) decision making, (3) leadership, (4) situation awareness, (5) mission analysis, (6) assertiveness, and (7) adaptability/flexibility. Analysis of the responses of 134 aviators' responses to the proposed dimensions also indicated these categorizations captured the vital aspects of aircrew coordination training (ACT). Unlike Fleishman and Zaccaro's (1992) taxonomy, Prince et al.'s categorization focuses on the interaction patterns of the team members rather than coordinated task performance outcomes.

Much of the USAF's research on combat air crews and airborne command-and-control teams has also emphasized the importance of these particular skill dimensions in developing effective team processes and enhancing team performance (see Cobb, 1998; Elliott et al., 1996; Elliott, Neville, Dalrymple, and Tower, 1997). While measuring the collective impact of these dimensions has presented problems for analysis, Prince et al. (1997) have found that team process measures can sometimes be effectively reduced to a single omnibus process score. Heffner (1996) used a similar aggregated construct to analyze team process in her examination of the impact of training on team mental models.

There has been an ongoing debate in the literature as to whether the decision to focus on a single omnibus measure (see Prince et. al., 1997; Heffner, 1996) or to separate behaviors into individual evaluations is more effective in testing hypotheses (see Cannon-Bowers et. al., 1992). It is not really clear in the debate if the issue is a matter of measurement or

construct assessment. The basic question, in my opinion, is whether there is a difference in assessing team behaviors in terms of their individual effect or as integrated components of a greater whole, such as team process. There seems to be much support for both camps. Further research is required to examine the theoretical implications of both positions.

In summarizing the existing research on team training, Salas et al. (1992) pointed out that informing team members of the nature and requirements of other team members' subtasks is an effective way to emphasize the need for communication and coordination. This cross training encourages team members to identify their interdependencies, recognize when and to where information must be transferred, and understand the consequences of failing to effectively coordinate their respective task responsibilities and decisions. According to researchers examining such cross training strategies (e.g., Cannon-Bowers et al., 1992; Stout, Cannon-Bowers, Morgan, & Salas, 1990; Stout, Salas, & Carson, 1994; Volpe, Cannon-Bowers, & Salas, 1996), the ability of one team member to anticipate the needs of another significantly enhances overall team performance.

Salas et al. (1992) asserted that effective teams operating under high stress conditions employ implicit coordinating mechanisms. These mechanisms are implicitly understood by the team members and require only minimum interaction within the team to coordinate specific actions. These behaviors and shared perceptions allow team members to anticipate others' needs while reducing the need for overt communication. When the unexpected occurs, or there are no standard procedures to follow, or a team member does not have the expertise needed for the task, interaction with other team members becomes essential for making effective decisions. Effective training enables team members to both develop these implicit strategies and understand how to react when they fail.

While there has been extensive research into the basic principles of team performance and training designs (cf., Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995; Morgan, Glickman, Woodward, Blaiwes, & Salas, 1986; Prince, Brannick, Prince, & Salas, 1997), Salas, Bowers and Cannon-Bowers (1995) pointed out that there has been almost no research that has focused on directly testing team training interventions. Research on training interventions has been concerned with comparing the effectiveness of various methods of conducting team training, e.g. video-based, lecture, information-based, behavior modeling, attitudinal, practice-based, individual vs. team training, whole vs. part training, and simulations (e.g., Andrews, Waag, & Bell; Bowers et al., 1993; Dwyer, Oser, Salas, & Fowlkes, 1999; Salas et al., 1992; Weiner, 1993), and developing adequate methods of training assessment (e.g., Fowlkes et. al., 1994; Gregorich & Wilhelm, 1993; McIntyre & Salas, 1995; O'Neil, Baker, & Kazlauskas, 1992). Salas et al. (1995) emphasized that these research efforts examining team training, especially in military settings, has mainly focused on developing models and taxonomies for developing team training programs. They pointed out while this research has provided a reasonable database for making preliminary recommendations to training designers, there is still much research to be done. Included in their recommendations is a call for empirical tests of various training strategies and determining how they are linked to team performance.

Cannon-Bowers et al. (1995) asserted that training must consider the competencies required for effective teamwork and the context in which the team performs. Different instructional strategies depend on the team's context, the nature of the task, and the composition and characteristics of the team. In operational military settings, aircrew training first builds a foundation of knowledge needed to understand how a particular aircraft or

weapon system operates. As suggested by many researchers (cf., Cannon-Bowers et al., 1995; Marks et al., in preparation; Stout et al., 1997) and required by established military training directives, military trainers rely on detailed task analyses of what KSAs are required for military members, including aircrews, to effectively carry out their assigned responsibilities. As observed by Stout et al. (1997) in their study of Navy aviation trainees, students progress through increasingly difficult tasks and examinations as they complete their training program. In operational military aircrew training, important considerations include not only the individual and team competencies required to fly the aircraft, but also the KSAs required to plan military combat operations to fulfill mission objectives. It is accomplishing these specified goals that ultimately determine the success or failure of any military operation.

Marks et al.'s (in preparation) taxonomy emphasized the importance of planning skills (i.e., mission analysis, goal specification, and strategy formulation and planning) as transition processes. Team communication, coordination, and other monitoring and back-up behaviors are central to action processes in their framework. Based on previous research (cf., Cannon-Bowers et al., 1992; Cannon-Bowers et al., 1995; Casner, 1994; Cavanagh, & Williams, 1987; Stout et al., 1997), training focused on improving team member competence in these processes, and thus enhance overall performance, must address planning or problem-solving KSAs in addition to more traditional KSAs characterizing team action process behaviors.

Based on Cannon-Bowers et al.'s (1995) conclusions and Marks et al.'s description, training on how to plan and formulate team-based strategies to achieve specified objectives should enhance a team's transition processes. As seen in earlier research (see Leedom &

Simon, 1995), training focused on improving team coordination behaviors should improve teams' action processes. As hypothesized earlier, this improvement of process behaviors should ultimately result in higher levels of performance.

Hypothesis 7: Teams receiving strategy training will exhibit more effective transition process behaviors than other teams.

Hypothesis 8: Teams receiving coordination training will exhibit more effective action process behaviors than other teams.

Due to the generally higher levels of ambiguity associated with complex situations, training interventions should both impact and be impacted by higher levels of environmental complexity. On the one hand, training should enhance teams' ability to cope with increasing levels of complexity in the task environment. On the other hand, increased levels of complexity should threaten to overwhelm the sometimes limited performance options developed by team members during training. Based on operational military experience and the research previously reviewed in this paper, this is especially true in conditions where teams must master and perform their tasks within a short time period. Therefore, I hypothesize that:

Hypothesis 9: There will be less difference in the performance of teams receiving strategy training versus those that do not (i.e., control) at lower levels of complexity than at higher levels.

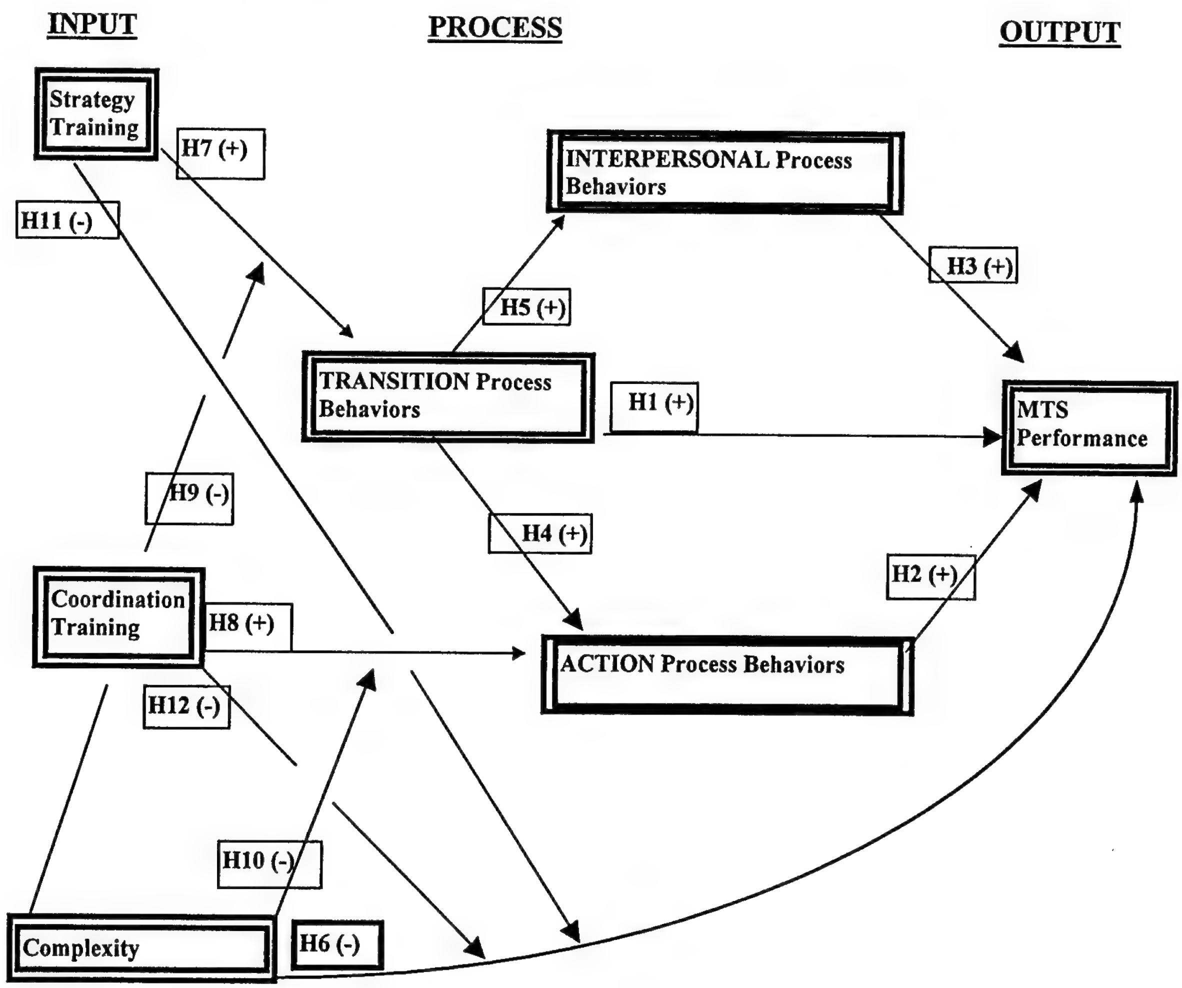
Hypothesis 10: There will be less difference in the performance of teams receiving coordination training and those that do not (i.e., control) at lower levels of complexity than at higher levels.

Hypothesis 11: Teams receiving strategy training will perform better in more complex situations than teams in the control condition.

Hypothesis 12: Teams receiving coordination training will perform better in more complex situations than teams in the control condition.

Figure 2 presents an illustrative summary of the hypotheses tested in this study.

Figure 2: Summary of Hypotheses



Chapter 3

METHODS

Participants.

Due to the large number of subjects required to complete enough four-person teams (i.e., two dyads for each MTS experimental session) to test the hypotheses described in this study, participants were recruited from two undergraduate subject populations: undergraduate psychology students and Reserve Officer Training Corps (ROTC) cadets and midshipmen.[4] Ideally, this study would have only used volunteer participants from the US Air Force (USAF), Navy, and Army ROTC programs. Due to their unique military and academic training, ROTC students potentially have greater experience in team-based tasks, command relationships, leadership, strategy formation, and task allocation than average undergraduate students. However, even with the direct support of the senior officer command staffs, there were not enough volunteers from this sample base to fully test the hypotheses in this study. It was necessary to complete the design with additional teams comprised of undergraduate psychology students.

As can be seen in Figure 2 (p.33), the proposed model theorizes about how manipulating three independent factors (i.e., two training conditions and environmental complexity) will directly and indirectly affect four dependent variables (i.e., MTS performance, interpersonal process behaviors, action process behaviors, and transition process behaviors). The proposed model employed a 2 x 3 x 3 mixed factorial and repeated measures design crossing environmental complexity (high vs. low) with training conditions (strategy, coordination, control) over three experimental sessions. Using both ROTC and undergraduate psychology students provided 36 MTSs, i.e. 6 MTSs in each experimental

design cell crossing complexity and training conditions, to test the hypotheses summarized in the proposed model.

Overall Participant Demographics. Performance and process measures were gathered for 36 four-person teams (N = 144). Reflecting the emphasis placed on their recruitment for this study, the majority of participants were undergraduate ROTC students (92; 63.9%). Students current enrolled in undergraduate psychology courses comprised 48 (33.3%) of the remaining participants. Table 1 provides a summation of the subject population assigned to each experimental condition. Work continued on the computer simulations and presentations supporting additional experimental conditions as subjects were being observed in coordination training and low complexity conditions, which were the first to be developed. Teams were randomly assigned to experimental conditions as they became available. Performance scores from single-limb and dual-limb visual tracking tests developed by USAF researchers at Brooks Laboratory, San Antonio TX, were used to assign subjects to each dyad (i.e., lead or wing aircraft) and their aircrew position (i.e., pilot or weapons specialist).

Reflecting the male-dominated composition of the ROTC detachments, 68.8% of the participants were male, while 27.1% were female. Six participants in the study failed to designate their sex during preliminary biodata collection. The participants ranged in age from 18 to 31 (mean = 20.04 years). The majority of participants identified themselves as Caucasian (79.2%) while the remainder were almost equally divided into several minority groups (Asian American: 6.9%; African-American: 4.9%; Hispanic: 4.2%) (see Table 2).

There was also one four-person team participating in this study composed of undergraduate student members of a local gaming association. These individuals were interested in participating due to their interest in gaming simulations, such as the one used in

this experiment. Although experienced in computer games of many different varieties, discussions with the team members indicated this was their first experience with air combat simulations. Due to their low number and greater similarities with the ROTC sample population, especially given their greater familiarity with each other, it was decided to include this team in the ROTC sample for all analyses in this study. To further minimize their potential impact on the study's design, they were assigned to the control condition.

ROTC Participants. After discussing the potential training benefits and the general nature of the study with each of the ROTC detachment commanders, I was permitted to recruit volunteers from each of the three ROTC units – U.S. Air Force, U.S. Navy, and U.S. Army. Additionally, I demonstrated the simulation to staff representatives from each service detachment. This demonstration provided each of the detachment commanders with a better understanding of the nature of the experiment and the potential benefits it held for enhancing their military training. Although the simulation used in this study was most relevant to Air Force training and education objectives, each of the commanders decided to support the study and recruit volunteers from their cadet and midshipmen populations.

The commander of each detachment appointed a representative to act as recruiter and schedule coordinator for the study. This individual was responsible for publicizing the study among the ROTC students, signing up volunteers, and working with the experimenters to schedule experimental sessions. While the Air Force and Army detachment representatives were students who were enrolled in the program and interested in participating in the experiment, the Navy volunteer was their staff officer responsible for freshmen courses and military training. As one might have expected, since the computer simulation used in this study illustrated combat air operations as opposed to ground combat, most of the ROTC

participants in this study were from the USAF ROTC detachment (i.e. Air Force – 68 (73.91%); Navy – 16 (17.3%); Army – 8 (8.69%)).

While undergraduate psychology students received course extra credit for their participation, it was not possible to provide similar rewards to the ROTC participants. Due to the unique nature of the experimental simulation used in this study, the detachment commanders believed the training opportunities inherent in the simulation used in this study were adequate compensation for the cadets and midshipmen taking part in the study. The USAF ROTC staff also attempted to increase interest in the study by incorporating student participation and performance into their detachment competition for end of the year recognition awards. The award contribution from the study was based on the number of cadets participating from each cadet flight.[5]

After discussing possible motivational rewards with members of the senior USAF cadet command staff, the experimenter also agreed to provide refreshments for a study break for the flight finishing with the most points at the end of the experiment. Each participant's final performance scores were recorded and summed according to their flight assignment to determine the winner. Informal feedback from the participants indicated this enhanced their willingness to participate. Informal feedback also indicated that the majority of ROTC participants were primarily motivated by a desire to fly the simulation.

Once individual difference measures were collected, participants were assigned to one of two flight teams (e.g., lead flight team and wing flight team) based on pre-determined performance criteria. To enhance the learning outcomes for their training, the detachment commanders required that students from the ROTC units organize their own four-person teams. Once they arrived for their experimental session, ROTC rank was used as the primary

criteria for deciding which students would be pilots. The two highest-ranking cadets/midshipmen were designated pilots, while the two lower ranking individuals were designated as weapons specialists and randomly assigned to the two simulated aircraft. The highest-ranking cadet/midshipman was also designated as the formal leader, i.e. mission commander, of the team. If the participants were of equal rank, then their performance on the psychomotor test battery was used to make these determinations with the higher score receiving the designation.

Undergraduate Psychology Students. Forty-eight (33.3%) of the participants were recruited from undergraduate psychology courses following procedures established by the university and psychology department. As mentioned earlier, subjects were randomly assigned, times permitting, to the three experimental conditions, i.e. coordination training, strategy training, and control. Unlike the ROTC participants, undergraduate psychology students received extra credit course hours (total = 5) as compensation for taking part in the complete study.

Subjects were required to attend two research sessions. During the first session, extensive biodata was collected on the subjects for later analysis. Subjects also completed the psychomotor test battery mentioned earlier. The session lasted about one hour, so subjects received one hour of extra credit as compensation. At the end of this session, subjects scheduled their experimental session. Although encouraged, subjects were not required to attend both sessions to receive any portion of the total extra credit hours approved for participating in this study.

Once arriving for their experimental session, participants were assigned to one of two simulated aircraft, i.e. lead or wing. Subjects scoring highest on the psychomotor test battery

were designated as pilots. Those with the highest scores were designated as the leader, i.e. mission commander, of their four-person team. The lowest scoring individuals were randomly assigned as weapon specialists. After completing all experimental mission simulations, or when the four-hour time limit expired, subjects received an additional four extra credit hours for their participation. If time was running short, teams were asked if they wanted to continue the experiment or wished to terminate. No experimental missions were begun unless time, either defined by the scheduled limits or by the team's decision to continue, permitted their completion. Each of the 36 teams participating in this study completed each of the three experimental mission simulations.

Analysis of Potential Sample Population Effects. As described earlier, the design of this study was a 2 x 3 x 3 mixed factorial design with four dependent variables (i.e., performance, interpersonal process behaviors, action process behaviors, and transition process behaviors). In order to check for any differences due to subpopulations (i.e., ROTC vs. undergraduate psychology students), a series of subanalyses was completed to determine if sample population was exerting any significance effects on each of the dependent variables.

According to these analyses (see Appendix B, Table 1), sample population did not significantly influence MTS performance (i.e., ROTC: mean = 125.42; Psyc: mean = 104.17). Teams comprised of subjects from one population sample did not perform significantly better or worse than teams composed from the other sample. The two samples also did not differ in their interpersonal process ratings (i.e., ROTC: mean = 3.13; Psyc: mean = 3.13) (see Appendix B, Table 2). However, as seen in Appendix B, Tables 3 and 4, population type did significantly influence action and transition process behaviors. ROTC

students received higher ratings and scores on these two variables (i.e., action: mean = 3.37; transition: mean = .47) than their undergraduate psychology student counterparts (i.e., action: mean = 2.70; transition: mean = .006). However, it was decided that these effects did not require additional controls within the later analyses since the primary dependent variable in the model, i.e. MTS performance, was not significantly affected by population type.

Simulation.

Overview/layout. Two pairs of subjects, functioning as two separate combat aircrews, were electronically linked together in an integrated multi-team low-fidelity environment. Although the two personal computers (PCs) had identical capabilities, one computer station was designated as the lead flight, while the other functioned as the wing flight (see Appendix C). While each team controlled the flight and operation of their aircraft, the two teams were linked, both electronically and by task requirements, in a multi-team operation.

Based on earlier research on task requirements associated with maintaining aircraft in flight (see Casner, 1994), feedback from an experienced USAF instructor pilot, and SME judgments, mission task responsibilities were divided between the pilot and weapon specialist positions (see Table 3). The goals for this task allocation were to reflect the established division of work required to control, guide, and navigate aircraft in flight (see Casner, 1994), while creating interdependency between the two team members within each aircraft. As discussed earlier, the lead aircraft's pilot acted as the designated mission commander (i.e., leader) for the two teams. As such, he/she had final decision making power for resolving problems and achieving objectives during the simulation.

There was a four-way wooden partition separating team members and teams (i.e., lead and wing) from one another. The PC monitor output was split so that each dyad (i.e. pilot and weapons specialist) had access to exactly the same visual information. The layout also prevented a subject from directly interfering or intervening in the actions taken by their team partner or the other team. The teams' only link to one another was through verbal communication over their headsets.

Hardware: Audio. Each team member had a microphone-equipped headset to communicate with their partner and the other team (i.e. lead and wing), collectively. When activated by the weapons specialist, between team communications were open to both the pilot and weapons specialist positions simultaneously. Teams could not control these communications in such a way to conduct "private" conversations between individuals (e.g., pilot to pilot, weapons specialist A to pilot B). The weapons specialist controlled the type of communications (i.e. within or between teams) used by their team by activating a switch on a control box connecting the team to their counterparts.

Simulated combat sounds, communications from computer controlled entities (i.e., all aircraft other than the experimental teams), and automated audio prompts and status reports embedded in the simulation program were presented in stereo in the headsets. Communications within and between teams were heard in mono channels. This permitted these communications to be isolated to the left earphone, for within team communications, and the right, for between team communications.

This audio set-up not only reflected some of the very basic attributes of operational systems presently in use by airborne command-and-control teams, but it provided the subjects with an additional audio cue to distinguish the source and identity of audio inputs.

This system also enhanced the ability of SME evaluators monitoring the teams' performance and actions to locate the source of contextual cues used by the teams during the simulation. Subjects did not have the ability to eliminate this "background" noise other than completely removing their headsets. Subjects were also directed to conduct all conversations during the experimental session through the attached microphones and headsets, thus permitting their audio transmissions to be recorded for later analysis.

Hardware: Computers. The flight simulation used in this study were run on a 100 Base TX, TCI/P local area network (LAN) of Pentium II 300 PCs. Each PC contained 64MB of RAM and a Direct3D video accelerator with 3 MB of video RAM running under Win95. Individual teams operated off a single CPU. A video splitter was used to transmit the video signal from this unit to the pilot and weapons specialist positions. This layout allowed both participants within a single aircraft to view exactly the same video displays at exactly the same time. Both subject positions had 19" SVGA monitors set at 800X600 resolution to view the video signal. Additional similarly configured PCs were available on the LAN for mission editing, recording flight information, and functioning as an experimenters' station.

The subject operating as the pilot used a mounted Thrustmaster F-22 joystick and a F–16 Throttle Quadrant System to control the flight of the aircraft. The joystick was programmed to permit the pilot to not only maneuver the aircraft, but various buttons and switches allowed him/her to alter the team's cockpit views, fire weapons, and activate air brakes. The throttle allowed the pilot to control the simulated aircraft's airspeed.

The weapons specialist used a standard PS2 style keyboard to perform his/her various tasks. Since time for training was limited, approximately 45 minutes to an hour, several keys were highlighted with color-coded combinations and labels to help the weapons specialist

carry out his/her tasks (see Table 3). Chief among these tasks were selecting appropriate weapon systems for a selected target, creating "shoot lists" for the active weapon system, cycling targets, and aiding the pilot's efforts to avoid enemy attacks by releasing chaff and flares (defensive "missile decoys") and controlling aircraft electronic emissions (i.e., EMCON). Teams were taught that they should maintain a low level of electronic emissions, i.e. remain stealthy, while merely traveling along their flight routes. They also understood the importance of increasing their EMCON settings when it came time to aggressively seek out and destroy targets.

Hardware: Data Recording. All audio communication between and within teams, in addition to all game sounds, were routed from the audio mixer to a stereo VCR. By using a video splitter, each team's video displays were also captured and recorded. This layout provided experimenters and SME raters with an excellent method for verifying team actions and performances after mission completion.

A built-in feature of the simulation used in this study is an Air Combat Maneuvers Instrumentation (ACMI) program. This program created a complete digital recording of the team's actions, in terms of their assigned aircraft, during an experimental mission. These recordings were stored in a compressed digital file and are available for later review in much the same way that one operates and watches a VCR recording. ACMI files can be viewed from a number of perspectives including a cockpit view (akin to what the players actually saw during the mission), a top-down satellite view, and even a "free" view whereby an operator can freely adjust the view to any position.

Experimenters reviewing a team's performance can toggle on/off various labels identifying each specific entity, weapon fired, and other pertinent information. These files

also contained a running data log of events such as weapons fired, targets damaged or destroyed, and the exact flight path that an aircraft took. Due to their high fidelity, and the design of the experimental missions (discussed later), these files were used to score the combined teams' performance during each experimental mission.

Software: Simulation. A low fidelity, PC based flight simulator—F22 Total Air War (TAW) (Digital Image Design (DID) Limited, 1998), was used to create the experimental conditions needed for this study. This commercially available software contains a computer generated simulation of the F-22 aircraft immersed within a dynamic combat environment. Unlike its current prototype counterpart, the F-22 aircraft depicted in the simulation is equally capable of air-to-ground and air-to-air operations. Although it was possible to place the subjects in virtually any type of combat aircraft, using the F-22 simulation increased the survivability of the teams by providing additional protection through simulated stealth capabilities. These capabilities generally reduced a simulated enemy's ability to detect and target the subject team. It was believed that this capability was necessary to provide participants with an adequate chance to complete the experimental sessions, given the limited amount of time available for training.

Over 50 other types of allied and enemy aircraft were available for any given mission in TAW, and over 30 types of ground units and 20 types of ships may also be depicted in any given mission scenario. Additional military aircraft modeled in TAW included transports (e.g., C-130 Hercules; II-76MF Candid), air refuelers (e.g., KC-135R Stratotanker; Il II-78M Midas), airborne command & control (e.g., E3 Sentry; A-50 Mainstay), reconnaissance (944B Dark Star, Mig-25RB Foxbat), strike (e.g., Tornado, Mig-27 Flogger), fighter (e.g., F15C Eagle, SU35 Flanker), and helicopters (e.g., AH64 Apache, Mi-24D Hind). The

simulation also included civilian jets (e.g., Lear Jets, Boeing 767). Ground forces depicted in the simulation included civilian (e.g., trains; limousines) and military supply vehicles (e.g., Humvees, Bedford trucks), light armor (e.g., M-163 Vulcan, BMP-3), heavy tanks (e.g., M1 Abrams, T-80), surface-to-air missile launchers (SAMs) and anti-aircraft artillery (AAA) vehicles. Ships can range from civilian (e.g., ferries, oil tankers), to military light attack (e.g., Hovercraft, gunboats), heavy attack (e.g., various Destroyers and Battle ships), and aircraft carriers (e.g., Nimitz class).

TAW also had the capability to include up to 16 countries (e.g., US, Russia, Sudan, Ethiopia) during any mission or campaign scenario. While traditional NATO and other alliances were available in the simulation, the mission designers and experimenters could have selected any other alliance combinations. The important consideration for subject teams was that in any given flight, it was quite likely that multiple allied, enemy, and neutral entities would be present. This consideration limited the effectiveness of video gaming strategies relying on attacking and destroying everything the player encountered during the experimental missions. Just as in operational combat missions, there are many actors to consider when waging war.

While naturally limited to what can be depicted on a PC screen, aircraft flight modeling and weapon envelopes were generally consistent with publicly available information. For example, all aircraft could only fly as high, fast, and far, corner and otherwise maneuver, carry weapons, sustain damage, etc. as described about their operational counterparts in the open press. Moreover, weapons were only as capable and effective as discussed in open sources. The actions of ground and naval units are similarly well modeled.

Software: Displays. Although the view could be altered by the pilot to simulate a

combat pilot moving his/her head to look around the cockpit, the team's primary view was looking straight out of the aircraft's canopy. Superimposed on the windscreen was a HUD that normally provided information about the team's current: 1) altitude; 2) heading; 3) airspeed; 4) engine speed; 5) flight attitude (i.e., pitch and yaw); 6) gravitational forces experienced; 7) EMCON setting; 8) direction to the next waypoint; and 9) mission time remaining, along with additional information depending on its setting. Three additional HUDs were available to the team and under the weapon specialist's control.

In the air-to-air (A2A) and air-to-ground (A2G) modes, weapons selection and number available were displayed. Additionally, each mode presented the team with valuable information when air or ground targets were selected. In the A2A mode, position and flight information (i.e., speed, altitude, heading, distance, closing velocity, and aircraft type) was provided on "targeted" enemy aircraft. Notably, because of the advanced radar and electronic identification capabilities associated with the F22 in the simulation, it was not possible to lock A2A weapons on to allied aircraft. The A2G mode also displayed critical range-to-target information about selected ground targets. Since ground vehicles had no means of electronically identifying themselves, teams had to use visual displays in the cockpit in conjunction with HUD information to avoid attacking friendly forces.

Finally, the navigation mode provided team members with vital flight route information. Using this HUD, teams could see if they were off their preplanned flight route in terms of speed, altitude, heading, and timing. Although not normally a factor during the missions used in this study, teams could also view their fuel status. During combat, when the other HUDs are depicting important targeting information, teams could quickly go to this HUD to determine their position relative to their preplanned flight route.

After being activated by the weapons specialist, two additional displays were superimposed on the bottom corners of the HUD. Both provided a top-down overview of the subjects' position and the objects around their aircraft. Various types of information on both displays were color coded for consistency and to enhance their cue value. In addition, the range for both displays could be adjusted by the weapons specialist from 15 to 250 nautical miles in five graduated steps.

On the lower left of the computer screen was a display that focused on targets and threats to the team. This display included distance rings so that teams could estimate how far away any given target was from them. If a target is "locked-on" (i.e., selected for attack) by the team, it was highlighted. A team could also determine if any enemy vehicle or aircraft was attempting to lock on their position using radar. In addition, incoming and outgoing missiles, enemy and neutral aircraft, and ground air defenses were depicted and color-coded on this display.

On the lower right of the computer screen was a second situational display. In addition to the information about the position of objects in the team's proximity in the target-threat display, this display included a copy of the team's preplanned flight route. Key in this display were the locations of geographic markers, called waypoints. These waypoints acted as reference keys for all the team's required actions. Although radar signatures were not displayed on this "aid," it provided the team with an important source of information for maintaining their flight course and orienting themselves to their environment.

In addition to the various visual displays described above, the TAW simulation provided various auditory cues to enhance the "realism" of the simulation. Notably, the game provided state-of-the-art modeling of weapons launches, explosions, and engine noises.

In addition, specific auditory cues included an electronic verbal "shoot" command when selected targets came within the effective range of the team's weapon system. Team members also received a verbal "missile launch" warning when fired upon by an enemy missile launcher or aircraft. Simulating a radar attack warning alarm in real combat aircraft, a continual auditory warning sound was provided as long as a missile maintained a lock on the team's aircraft. If hit by enemy fire, the subjects not only heard the impact, but also verbal warnings of aircraft systems failures.

Software: Mission Scripting. Weaver, Bowers, Salas, and Cannon-Bowers (1995) emphasized that experimental team tasks must provide a situation in which multiple operators are required to interact in an interdependent manner. However, Kozlowski and Gully (1996) insisted that typical laboratory settings "...lack the complexity, dynamics, and emergent characteristics that make NDM [natural decision making] tasks so unusual and challenging" (p.3). They and other researchers (e.g. Goodwin, 1997; Mathieu & Goodwin, 1997; Stout et al., 1990; Kozlowski & Gully, 1996; Weaver et al., 1995) have been successful in employing low-fidelity personal computer (PC) flight simulations to study team behaviors and effectiveness.

Kozlowski and Gully (1996) contended that the key to making computerized simulations useful is their degree of psychological, not just physical, fidelity to the actual field situation. They used the term psychological fidelity to refer to "...the degree to which key factors and processes activated by the simulated situation mirror characteristics in the natural situation" (Kozlowski & Gully, 1996, p.9). While PC-based programs lack the "realism" present in high-fidelity military and commercial airline simulators, they have proven effective in isolating team constructs and behaviors using novice subject populations.

These relatively basic simulations have provided researchers the opportunity to employ novice subjects with minimum familiarization training, thus allowing them to maximize their use of abundant student populations rather than depending on more limited expert subject populations.

As in other PC-based simulations, the Air Campaign Effectiveness Simulation (ACES) employed in this study provided a rich and dynamic team performance environment. For example, during one mission employed in this study, teams beginning the simulation were immediately confronted by potent enemy air defenses operating just beyond their weapons range. As the teams adjusted their flight altitude, in accordance with mission guidelines, they noted several friendly aircraft moving toward and engaging these enemy positions. Despite being sighted and "locked on" by the enemy's tracking radar, teams had to ignore the more distant threat to locate and identify a more immediate threat closer to their position but hidden from their view by the surrounding terrain.

Once this threat was disposed of, teams had to find their way to their next assigned target's location by following a river winding its way through the area. Along the way, they encountered many friendly ground forces and moved through areas where aircraft were engaged in pitched combat. The teams also had to avoid destroying neutral passenger ferries being harassed by enemy hovercraft and patrol boats, while destroying the enemy vessels.

As they arrived in their main target area, teams had to distinguish the enemy ground forces from friendly ground forces moving to attack them. Despite many opportunities to attack enemy air forces operating in the area, teams were required to focus on their assigned ground targets and rely on computer controlled allies for their air defense. While this dynamic environment presented the MTS with many challenges, it also presented

experimenters with many unique challenges to create it.

Based on feedback from operational experts[6] and professional military colleges,[7] TAW provided an unique PC-based software platform for creating and realistic challenging combat missions. Thanks to the recommendations of the TAW software designers, an editing program was used to control the exact conditions and events comprising each training and experimental mission. The Air Defense Fighter Graphic User Interface Editor (AGE), version 2.14, Independent Mercenary Corps (IMC), software program provided the capability to script simulated mission parameters to the specifications required by the experimental conditions employed in this study.

This editing program allowed programming control over every aspect of the battle situation (e.g., the number and types of allied and enemy aircraft present and their flight paths, the number and types of allied and enemy ground units and their actions, waypoint placements, weapons loads, etc.). This control was needed to tailor the embedded events within the experimental missions used to evaluate subject team performance. Once missions were programmed, they underwent extensive trial runs with research assistants and subject volunteers. Any flaws in the mission programming or inconsistencies with the experimental objectives for any particular mission were immediately corrected and tested.

Given that basic design, researchers then relaxed certain parameters (e.g., the number and types of enemy fighter aircraft, the number and quality of enemy surface-to-air units) to make them playable by novice teams in a 15 minute time period. It was also decided that the experimental missions would focus on A2G operations, rather than attempting to control a more fluid air combat scenario. Ground units were selected as primary and secondary targets so that they would be easily distinguishable by novice teams. To clarify performance

scoring, these selected targets could only be destroyed by the participants. Thanks to the control provided by the editing program, no other computer controlled entity would engage these targets.

In addition to training missions, three experimental missions were designed and tested. These missions were calibrated to be essentially parallel, in that the number and types of enemy and allied aircraft and ground units were held within specified ranges regardless of experimental condition (see Table 4). Review by TAW subject matter experts (SMEs) and initial pilot testing suggested that these three mission simulations represented equally challenging scenarios. Analysis of the potential effects of mission order and timing confirmed the SMEs' judgments that the missions were generally equivalent (see Table 5).

A series of one-way ANOVAs were conducted to determine if the order the mission occurred significantly influenced teams' performances. As reported in Table 5, the order in which the three missions occurred did not significantly affect MTS performance (Ridge Jumper: $F(2, 33) = .88$, n.s.; Canyon Sweep: $F(2, 33) = 1.61$, n.s.; River Run: $F(2, 33) = .95$, n.s.). This analysis indicated that there was no advantage in having one mission versus another at any given time in the experiment. For example, it didn't matter if teams flew the River Run mission first, second, or last, their performance scores were comparable across time.

A similar analysis was also completed to determine if the time, i.e., mission 1, 2, or 3, a mission occurred impacted the teams' performances. As indicated earlier, this analysis showed that mission timing did not significantly influence MTS performance (Time 1 (T1): $F(2, 33) = 3.12$, n.s.; Time 2 (T2): $F(2, 33) = .78$, n.s.; Time 3 (T3): $F(2, 33) = .104$, n.s.) (see Table 5). In other words, there was no advantage as to which mission occurred at any

given time. For example, it didn't matter if teams flew Ridge Jumper, River Run, or Canyon Sweep during the first mission, their performance scores were comparable across missions. In summary, the missions were found to be roughly equivalent and comparable across the experimental conditions.

Premeasure Session.

Data were collected in several stages during two experimental sessions, as mentioned earlier. Together, the two sessions lasted about 4.5 to 5.0 hours and were partitioned into five phases: (1) premeasures, (2) pre-training assessment, (3) task training, (4) team training intervention, and (5) mission engagement. During the first *premeasures session*, which lasted about one hour, participants completed a battery of survey measures relevant to research objectives of the overall laboratory study. Information collected from the subjects included personality measures, KSAOs, background data, and demographics (i.e., sex, ethnicity, academic year, GPA, and GRE scores).

As discussed earlier, participants also took two specially adapted psychomotor tests to assess their capability to track objects in a visual field while manipulating electronic controls, i.e. joystick and throttle. Performance scores from single-limb and dual-limb visual tracking tests, developed by USAF researchers at Brooks Laboratory, San Antonio TX, were used to designate pilots and mission commanders among the participants. These tests were adapted from the USAF's Basic Attributes Tester (BAT) programs. The BAT provides AFROTC a means of obtaining important selection data on pilot applicants early in the selection process. The BAT incorporates computerized testing technology to measure psychomotor, cognitive, and personality attributes that correlate with operational pilot performance. (AFROTCI 36-6,

25 Sep 95.) Although the order of the tests in the battery used in this study could be altered, all participants took the tests in the same order.

The first of the two tests, *Arc Pursuit*, was a single limb test based on Melton's (1947) original work for the U.S. Army Air Force. According to Chaiken, Kyllonen, and Tirre (under review), this test required participants to use the joystick to control the movement of two parallel yellow lines, with five degrees of separation, within a 140-degree arc-shaped window. This arc track measured four centimeters in height and 26cm horizontal distance between outer arc endpoints. Participants were required to keep their yellow lines as close as possible to a single red line target. The target moved along the arc at varying speeds and reversed directions once it reached the outer left/right boundaries of the arc. Target movement was determined by randomly combining seven rates of speed, ranging from 35 to 140 degrees per second, and three levels of duration, ranging from 900 to 1900msec, with the constraint that no two consecutive speeds were identical (Chaiken et al.). Each trial, one practice and three assessments, lasted 35 seconds and was followed with feedback detailing what percentage of time the subject was on or close to the target. The assessment trial performances were combined by a programmed algorithm to calculate a final performance score on the overall test. This score was recorded for each participant and was used as a secondary criteria (i.e. tie breaker) for designating pilots and mission commanders. This test was programmed to appear first because it required only single limb coordination and provided participants, particularly those without any experience using joysticks and throttle controls, with a chance to familiarize themselves with the controls used in the second test and the experimental sessions.

The second test, *Pop the Balloons*, required subjects to move a speed mapped throttle and joystick to control the y and x axis movement, respectively, of a target sight on the computer screen. By maneuvering the sight directly over color designated target balloons (purple) and activating the triggering mechanism on the joystick, participants could pop the balloon and score points. If he/she failed to pop the targeted balloon within ten seconds, it turned red for two seconds before it burst on its own. Subjects could still gain credit for the balloon by popping it before it burst. The test was set to last four minutes without any practice session. The test began with seven nontarget balloons (yellow) and one purple. Each time a balloon was popped, one of the remaining yellow balloons turned purple. Once all eight had been popped, eight more balloons appeared. Feedback was given at the end of the time session in terms of number popped and number timed out. These scores were recorded for each participant.

Since this test required subjects to manipulate throttle and joystick controls to maneuver the "pin" over a moving target, it was decided that subjects' scores on this portion of the test, i.e. the number balloons popped, would be the primary selection criteria for designating pilots and mission commanders, as previously described. SMEs indicated that maneuvering to destroy moving balloons was most analogous to the actions required of pilots in the simulation. Since the best performing pilots usually become mission commanders, the highest scorer among the four team members was designated the mission commander in each undergraduate psychology team. As described earlier, this score was used as a secondary criterion for designating mission commanders and pilots on ROTC teams.

Once the participants had completed all premeasure surveys and the psychomotor tests, this premeasure session was complete. After receiving their one hour of extra credit for

participating in the session, participants scheduled themselves for the experimental sessions. Other than descriptive demographic information and using the psychomotor tests as selection criteria, the data collected during the premeasure sessions was not used in this study. It has been included in this discussion to maintain comparability with previously collected data and to provide a perspective of the actual requirements levied onto the participants.

Experimental Sessions - Training.

Task Training. Following recommendations made by Cannon-Bowers et al. (1995), team members were guided through a structured hands-on task training session based on the competencies required by the simulation (see Table 6). Training focused on the task competencies relevant to each position (pilot or weapon specialist) by an extensively trained subject matter expert throughout the *task training* phase (see Table 7). After a general, ten-minute presentation reviewing the nature and purpose of the study, participants received approximately 35-45 minutes of initial task training prior to the training intervention and participating in scripted combat missions (see Appendix D).

These initial training sessions focused on ensuring the subjects were adequately proficient in performing their individual task responsibilities (e.g., flying and maneuvering the plane, weapon selection, locking onto enemy targets, firing at enemy targets, etc.) while becoming familiar with their partner's responsibilities (see Table 3). Due to the nature of the experimental missions, instruction concentrated on flight operations and the air-to-ground task areas while ensuring team members had a basic mastery of the air-to-air combat tasks.

In the final portion of their training, participants completed a joint (i.e., all four team members) practice session which emulated the general task and teamwork requirements existing in the experimental mission scenarios (see Table 6). As in the experimental

missions, the two dyads (i.e., lead and wing aircraft) had to work together to achieve specified mission goals in the multi-team ACES simulation. This set-up reflected the two-ship (i.e., two aircraft) formation normally characterizing minimum USAF requirements for tactical air combat operations.

Just as during the experimental sessions, teams received a printed copy of their specific mission objectives, pictures of their assigned targets, and a map of their assigned flight route to reference during the practice mission simulation. Additionally, pictures identifying the various vehicles and aircraft used in the simulation were posted at each subject station. Unique HUD references were displayed at each experimental station for the subject's easy reference during the simulation.

The task training session contained built-in competency checks to ensure participants were able to carry out the tasks required of them in the simulation. During each phase of the task training session, the assigned SME instructor assessed his/her participants' performance in each competency area (Table 7). Based on these observations, the trainer determined if the participants had acquired the necessary task competencies to continue in the experiment. Any knowledge and skill deficiencies were immediately addressed by the trainer (e.g., verbal explanation). Following this retraining, subjects could be given a second opportunity to fly a portion of the joint practice mission, if time permitted.

While this procedure implied that some subjects may have received more training time than others, I do not believe this provided them any advantage in the experimental sessions. Teams and the individuals composing them were trained to achieve equal levels of task competency before continuing in the experiment. Based on such an approach (cf., Cannon-Bowers et al., 1995; Goodwin, 1997; Heffner, 1996; Salas et al., 1992), it is not

necessary to duplicate identical training conditions for each individual to achieve equal levels of competency in the tasks required by the experimental simulations.

Team Training Manipulation. In the *team training intervention* phase of this study, team members were guided through one of three, structured team training sessions: strategy training, coordination training, or a control session. Each training condition employed a twenty-minute presentation supervised by an extensively trained SME. Each presentation reviewed general team mission responsibilities and basic team processes (e.g., mission analysis, strategy formulation/planning, goal specification and formulation, systems monitoring, timing/coordination, etc.) as described in Marks et al.'s (in preparation) taxonomy. Each presentation also followed the same basic format.

Initially subjects were presented with an overview of the concepts covered by the presentation. Then, using a mixture of bulleted slides and recorded video segments, each of the process behaviors described by Marks et al. (in preparation) was defined and discussed. Following specially tailored presentation scripts designed to limit the concepts covered in the training condition, experienced SMEs posed as team members modeling the behaviors described in the presentation. Each presentation ended with a summary, on slides and in audio, of the main concepts covered during the training session. To reinforce these points, subjects were verbally questioned about the central characteristics of the process behaviors described and demonstrated by the presentation.

Specifically, the strategy training presentation reviewed each of the transition process behaviors discussed by Marks et al., i.e. goal specification, mission analysis, and strategy planning and development. By the end of the training session, each subject should be able to identify their primary and secondary objectives (goal specification), understand why they

need an appreciation of the other operations going on around them (mission analysis), develop a set of primary and contingency plans to accomplish their assigned mission objectives (strategy formation and planning). Following training, students responded in writing to an open-ended question designed to assess their knowledge of the concepts described in the session. Additional questions also assessed their knowledge of those concepts reviewed in the other training conditions. These responses were later analyzed for their accuracy and content.

The coordination training presentation reviewed each of the action process behaviors discussed by Marks et al., i.e. checking progress toward objectives, monitoring their environment (both inside and outside of their combat aircraft), backing up teammates, and coordinating actions between teammates. This training was designed to review those behaviors required for a single dyadic team (i.e., a pilot and weapon specialist) to coordinate their actions. By the end of the training session, each subject should be able to demonstrate each of these behaviors while flying their assigned missions. As in the strategy training condition, students responded in writing to open-ended questions designed to assess their knowledge of the concepts described in their assigned training session as well as their knowledge of those reviewed in the other training conditions. These responses were later analyzed for their accuracy and content.

Flight teams in the control condition did not receive any type of team process training intervention. Subjects in this group viewed a twenty minute multimedia presentation consisting of scenes from the "Canopy's Up" and "Frontline Pilots" film series produced by Blue Heron Films. Although informative about the general nature of air combat, stealth technology, the F-22, and the special effects used in the TAW simulation to mimic

explosions and weapons firing, the videos did not contain any performance enhancing or instructional material relevant to the experimental conditions. As in the experimental teams, control subjects responded to open-ended questions that provided a manipulation check for the training interventions used in this study.

Following training and prior to beginning the practice MTS mission, participants were also tested about the task material presented to them. Included in their participant packages were ten multiple-choice questions assessing their knowledge of critical HUD information (i.e., task knowledge). These questions provided a measure of the subjects' task competency and knowledge. Their responses were compared to a master test key and scored for later analysis.

As mentioned earlier, subjects' responses to the three open ended questions served as manipulation checks for the training intervention conditions by querying them about key concepts reviewed in each of the training conditions. Using a point assessment derived from SME responses and a review of test subject responses, two SMEs rated the quality and accuracy of each participant's answers (see Appendix E). Analysis showed that the SMEs' ratings were significantly correlated with each other (coordination: .65, $p<.01$; strategy: .77, $p<.01$) (see Table 8). This indicated that the raters applied similar standards to the participants' responses and provided the justification for aggregating the two ratings into a single measure for later analyses.

As expected, analysis of variance and contrast analysis indicated that trained teams did significantly better than teams in the control condition on the knowledge question corresponding to their training condition (see Table 9). Additionally, these teams also performed better on their corresponding test item than teams in the remaining training

condition (see Table 9). Simply put, subjects receiving coordination training did better on the question focusing on coordination behaviors than subjects in either the control or strategy training condition. The same held true for subjects in the strategy condition relative to the question requiring subjects to list important factors in developing strategies and plans. This analysis also indicated that task knowledge was unaffected by training condition (Table 9). In other words, none of the training conditions either enhanced or degraded the subjects' task knowledge. Based on this analysis, the training manipulation was successful in presenting training most appropriate for one condition over another or the control condition.

Complexity Manipulation. As described earlier. this study employed a 2 x 3 x 3 mixed factorial design crossing environmental complexity (high vs. low) with training conditions (strategy, coordination, control) over three experimental sessions. Following Wood's (1986) research findings and conclusions, higher levels of complexity were created by increasing the component (i.e., features) and dynamic (i.e., predictability) complexity of the experimental sessions. Specifically, in high complexity conditions the variety of target objects at each designated location was increased, thus increasing the number of target features that the teams must distinguish to accomplish their assigned tasks (see Table 4).

For example, during one mission simulation, a team had to discern the differences between two types of boats – one enemy and one neutral. However, in the high complexity version of this same mission, participants had to distinguish between three types of boats – two enemy and one neutral. The important consideration in this problem was that only one type of enemy ship was assigned as either a primary or secondary target. As found in related cognitive research (see Treisman, 1991), this increased the complexity of the task for the teams by requiring them to distinguish between multiple features of the displayed targets

before taking action.

In the high complexity condition, teams also received less specific, more ambiguous information on the movement and location of potential target objects and threats than in the low complexity condition. In the low complexity condition, enemy and friendly forces were specifically identified by type, e.g., T-80 tanks and SU-27s. These reports also indicated where these forces were located relative to the pre-planned flight plan and waypoints (i.e., geographical markers on a map) in addition to more general grid coordinates. In contrast, the high complexity condition referenced objects in the mission area in more general terms – as friendly or enemy forces. Their locations were also described in terms of their general grid coordinates, which provided a much larger area for the team to potentially search for their targets. In this manner, teams in the high complexity condition were less able to predict the locations and possible actions of enemy forces than they could in the low complexity condition.

Embedded in the participants' experimental packets were several items, scaled one to five (ranging from strongly disagree to strongly agree), designed to assess subjects' individual perceptions of the complexity of their mission and task environment. Analysis of these five items indicated that four, i.e. items 10, 12, 13, and 14, were reliable and consistent indicators of the subjects' perceptions of the complexity of the environment in which they were immersed (T1: $\alpha = .66$; T2: $\alpha = .60$, T3: $\alpha = .58$). Item 10 indicated the subjects had to accomplish an unusually large number of tasks to complete the mission. Item 12 stated that the subjects were given accurate information to base their plans upon. Item 13 indicated that the mission was predictable and required only small adjustments to their plans. Finally, item

14 stated that the mission was easy and straightforward. Aggregating these responses provided a indicator of how complex the subjects perceived their task environment.

An ANOVA examined the subjects' perceptions of environmental complexity over time. Based on comparisons of their means across time, this analysis indicated that subjects failed to perceive any significant difference between the two complexity conditions (means: Low (T1) = 2.92, High (T1) = 2.93; Low (T2) = 2.91, High (T2) = 2.82; Low (T3) = 2.93, High (T3) = 2.95). The analysis also indicated that only a three-way interaction between time*complexity*training was significantly related to subjects' perceptions of the environment's complexity (see Table 10). This would seem to indicate that subjects' perceptions were more of a function of which training condition they were assigned than the level of complexity. In short, these analyses indicate that the manipulations used in this study failed to affect subjects' perceptions of their environment's complexity.

It is important to keep in mind that subjects only experienced one level of complexity (i.e., either high or low) throughout their experimental session. Based on previous research (c.g., Hackman & Morris, 1975; Salas et al., 1992; Saavedra et al., 1993; Wood, 1986) and the number of entities present in the subjects' perceptual field (see Table 4), the manipulations used in this study adjusted environmental complexity more in terms of degree (i.e., complex vs. overload) than in more absolute terms (i.e., mundane vs. enriched environments). The failure of these manipulations could indicate that a greater difference between the two conditions was required before subjects could perceive any significant differences. The addition of eight distracters (see Table 4) may not have been sufficient to alter the subjects' perceptions.

Experimental Sessions – Missions.

Teams began the final phase, *the mission engagement phase,* with an in-basket exercise and mission planning session. The purpose of these materials, as described in Chapter 4, was to assess important team process behaviors while providing teams with the information they needed to complete each mission. Once they had received their planning materials, teams were given ten minutes to plan their mission and select their weapons options (described in detail in Chapter 4). At the end of their planning session, the mission commander was interviewed to provide a summation of the team's plans and reasoning. Once this was completed, team members completed a series of short surveys before entering the experimental simulation. Team members were allowed to take important reference materials, i.e. printed flight map, pictures of assigned targets, mission brief detailing assigned mission objectives and flight requirements, into the simulation for later use.

As discussed earlier, teams "flew" three different air-to-ground combat missions following completion of their training. Although these missions differed in terms of terrain and specific mission objectives, they required the same task competencies and contained an equal number of potential ground targets (i.e., primary, secondary, and nonassigned) (see Table 4). Previous research employing an event-based strategy has well established the importance to hypothesis testing of standardizing the levels of performance across performance task conditions (see Dwyer, Fowlkes, Oser, Salas, & Lane, 1997; Fowlkes, Lane, Salas, Franz, & Oser, 1994). As can be seen in Table 4, experimenters designed the missions to be equivalent in terms of their mission objectives, i.e. assigned targets.

Each mission lasted 15 minutes, or until both aircraft were destroyed. If one aircraft was destroyed before the other, the "deceased" team remained at their station while their

partners continued the mission. The order of the experimental missions was counterbalanced to minimize any ordering effects on team performance measures. Although the experimenters attempted to achieve a complete counterbalanced design, it was not possible due to the problems in subject recruitment discussed earlier (see Table 11). However, as discussed earlier in this paper, neither mission order nor timing had any significant impact on MTS performance (see Table 5), so there was no order effect requiring counterbalancing in the design and analyses.

Once the mission was completed, the MTS was debriefed on their mission performance in terms of overall score, mission objectives achieved, number of assigned targets destroyed and, if required, the number of neutrals destroyed. Team members were directed to complete a series of post-mission surveys before receiving the in-basket and mission planning materials for the next experimental session. Their annotated maps and mission briefs were collected and labeled for later analysis. If additional missions remained, the team received the planning materials for the next mission. Once the planning session and interview were completed, the MTS returned to the experimental simulation.

Chapter 4

MEASURES

Multiple measures of team process and performance effectiveness were collected to accurately evaluate subjects' performance and provide the basis for later analysis. The dimensions described in Marks et al.'s (in preparation) taxonomy were operationalized to reflect the tasks and behaviors required by the simulation (see Table 12). These operational definitions guided the collection of data during the experiment and provided a sound foundation for analyzing the variables tested by the proposed model. They also provided the foundation for training SMEs on how to classify their observations and understand what particular observed behaviors contribute to different process and performance ratings, as described by Marks et al.

As will be described in detail later, scoring totals were computed based on the number of primary and secondary targets (i.e., mission objectives) destroyed by the MTS. These measures were used as objective indicators of the MTS's performance. SME ratings and measures of team process were central in testing the hypotheses proposed in this study (see Appendix F). Additional measures were collected (e.g., teams' affective reactions to the task, situation, and their performance, mental models, and shared mental models) as part of the project's larger data collection effort and research objectives. These data were not used to test any hypotheses proposed in this study.

This study employed a repeated measures design to increase the number of available observations per team and the power of the analysis due to a relatively limited number of available subjects (c.g., Cobb, 1998; Gully, 1994). SMEs rated team process behaviors evidenced in one of the two dyads comprising the larger MTS for each of the three missions. Following Dickinson and McIntyre's (1997) suggestions, raters used a behaviorally based,

BARS type scale to rate the team leader, each team member, and the overall two-person team on a five-point scale for each team process dimension described by Marks et al. (in preparation) (see Appendix F).

Team Process Measures - Transition Process Behaviors.

Marks et al. (in preparation) described transition processes as being characterized by behaviors directed at transforming work units and effectively responding to changes in the work environment. According to their description, transaction processes include mission analysis, goal specification and formulation, and strategy formation. Following Brannick et al.'s (1995) assertion that multiple observations were necessary to fully assess team and task process behaviors, several different measures were embedded in this experimental design to assess the quality of the MTS's mission analysis, goal specification, and strategy formation (i.e., transaction process behaviors).

Q-Sort. As previously mentioned in Chapter 3, the in-basket exercise consisted of giving each four-person team a variety of reports containing information both relevant and irrelevant to the team's assigned mission. The belief was that performance on this exercise would be indicative of the extent to which a MTS conducted a quality mission analysis. Reflecting the style and content of operational military reports, situational reports (SITREPs) contained information about the position, strength, and movement of friendly forces. Intelligence reports (INTEL) provided information about the position, strength, and movement of enemy and neutral forces in the team's mission area. There were five specially tailored SITREPs and five INTEL reports for each mission. Each of these items was previously rated by SMEs responsible for designing the experimental simulations for their usefulness/relevance to specified mission objectives (see Appendix G).

Participants were directed to sort the in-basket materials in terms of their importance, either very important, helpful, or irrelevant (i.e. useless) to their assigned mission. They were also instructed to accomplish this sorting as part of their mission planning. Each four-person team was given ten minutes to plan their mission and strategy, prioritize their goals and mission objectives, and refine their roles and responsibilities.

The subjects' final sort of the exercise materials, prior to entering the mission simulation, was recorded for comparison with SME derived rankings to determine their exercise score. Subjects received two points if they placed the report in the same stack as the a priori selection. If they were one position off, e.g. placing a report in the helpful stack when it should have been seen as irrelevant, they received one point. If they were two places off, e.g. treating an irrelevant piece of information as very important, the team received no points. This scoring method provided a potential range of two to twenty points for each mission. Since the entire four-person team participated in the sorting, these points were totaled and the score recorded for analysis at the MTS level.

Weapons Option Selection. Embedded in the teams' planning session and activities was the requirement for the team to jointly decide what weapons option to select. These options specified differing numbers of the air-to-ground weapons available for the team's use in the simulation (see Appendix H). Since the selection of weapons packages largely depended on the team's estimation of enemy threats and target requirements, this selection was believed to reflect the MTS's strategy development. As seen in Appendix H, teams could choose from three separate weapons options to arm both their aircraft (i.e., both aircraft were given the exact same number and type of weapons). While these options were the same for each experimental mission, there were differences in how effective each option would be

in any particular mission.

SMEs responsible for designing the mission simulations previously determined which option provided the most optimal weapons capability for each mission (see Appendix H). As in the in-basket q-sort, the weapons option selected by the MTS was noted and later compared with the SMEs' a priori rankings. Selecting the most appropriate option gained the team two points, the next most appropriate option resulted in a score of one, and the least was given a zero. Since the entire four-person team participated in the selection decision, the points were totaled and the score recorded for analysis at the MTS level.

Interview. Once the planning session was completed and the team's q-sort collected for later analysis, the mission commander was taken to a separate location to be interviewed. During this interview, he/she was asked several questions designed to provide a summation of the team's plans and strategy development (see Appendix I). The interview was recorded on audio tape and later evaluated by a SME who had not previously interviewed the subjects they rated nor acted as one of the primary instructors for the mission commander's MTS. As with other process ratings, behaviorally based BARS ratings scales were developed to assess the mission commander's interview responses (see Appendix J) in terms of the transaction phase behaviors described by Marks et al. (in preparation) (c.g., Dickinson & McIntyre, 1997).

Sixteen of the 168 mission interviews conducted during the study were randomly selected and rated by each of the three interview raters. The interrater correlations for the two sets of ratings were sufficiently high enough across each of the three transition process dimensions (goal specification: $r = .79$, mission analysis: $r = .87$, strategy formulation: $r = .84$) to permit viewing the SME ratings as equivalent. Therefore, as described earlier, only

one rater was used for each MTS participating in the experiment. Analysis indicated that the interview ratings were consistent measures over time (T1: $\alpha = .91$; T2: $\alpha = .90$; T3: $\alpha = .94$).

Summary Scores. The three methods of measurement, just described, provided two assessments of mission analysis and strategy formation, and one (i.e., the interview) score for goal specification. This was deemed to be a balanced measure of transition process, since the goals were specified in detail in the teams' briefings for each mission. Since each of these three transition process measures, i.e. q-sort, weapons option selection, and interview, used different scale ranges, it was necessary to standardize them in order to derive a composite score for transition process.

Analysis indicated that the three transition process measures were significantly related to one another (see Table 13). According to Table 13, the correlations between the mission analysis rating from the interview was significantly correlated to the q-sort results. This provided evidence that the different measures were tapping into the same domain -- mission analysis. The intercorrelations between the ratings for strategy formation, weapons selections, and the q-sort also provide evidence that the different measures were sampling the MTS's strategy formation behaviors.

Calculating Z-scores for each measure provided the means to compare and combine these scores across measures with different metrics (Cohen & Cohen, 1983). This linear transformation, and their significant correlation with each other, also permitted the scores to be combined into a single summary score for later analysis. The correlations noted in Table 13 also indicated that any composite of these measures could potentially be limited by possible multidimensionality between the two factors highlighted by the correlations, i.e. mission analysis and strategy formulation. Analysis indicated that these composite scores

were reliable measures of transition process behaviors over time (T1: $\alpha = .69$; T2: $\alpha = .70$; T3: $\alpha = .80$).

Team Process Measures – Action and Interpersonal Process Behaviors.

As discussed earlier, action processes involve team member behaviors associated with teams actually carrying out their plans and performance tasks. According to Marks et al. (in preparation), these processes include monitoring progress toward goals, systems monitoring (i.e., monitoring internal technology systems and the external environmental for changes and task cues), team monitoring and backup behavior, coordination activities, and communications between team members. Interpersonal processes, on the other hand, focus on those affect driven behaviors associated with reducing interpersonal conflict and keeping team members motivated (Marks et al., in preparation).

Following Dickinson and McIntyre's (1997) recommendations, behavior based BARS ratings scales were developed to assess each of the two-person teams within the MTS in terms of the action and interpersonal process behaviors described by Marks et al. (in preparation) (see Appendix F). The MTS instructor for each two-person team rated the effectiveness of his/her team members' behaviors in each of the action and interpersonal dimensions described in Appendix F. These ratings employed a five point scale, ranging from hardly any skill (i.e., 1) to complete skill (i.e., 5).

Unrestricted maximum likelihood analysis indicated that MTS instructors/raters were consistently able to reliably discern and assess the two process dimensions over time and repeated trials (see Table 14). Since these ratings were based on observations of the two-person teams (i.e., lead and wing) comprising the larger MTS, it was necessary to combine these ratings into a summary rating for the four-person MTS.

Although the correlation between the lead and wing dyads on the interpersonal BARS ratings were very limited over time (see Table 15), analysis indicated that the overall correlations for the two dyads were moderately significant (interpersonal process = .20, $p < .05$; action process: .45, $p < .01$) (see Table 15). Although these modest correlations indicate that that a composite of the two measures could suffer from relative low construct validity and internal consistency, it was determined that the correlations still permitted the means of the lead's and wing's interpersonal and action process behaviors ratings to serve as summary scores for the larger MTS. As described earlier, a composite score combining the teams' standardized q-sort score, weapons selections score, and interview ratings served as the measure of MTS transition process behaviors for later analyses.

Team Performance Measures.

As mentioned earlier, the existing TAW programs were altered to ensure teams were required to plan and follow strategies designed to accomplish assigned objectives to be successful. The control provided by the editing software allowed experimenters to isolate certain target types from the actions of any computer-controlled entity. This permitted MTS instructors and SMEs to calculate a team's actual mission score for the experimental mission by reviewing their observations and the digitized recordings of the team's performance.

For example, once an MTS had completed their assigned mission and the fifteen minutes time had elapsed, the subjects were directed to move to their planning area to wait for their mission debrief. Given that it normally took the two instructors a few minutes to compare their notes and score the mission, subjects could take a brief break between missions. Using digital recordings of the mission and a listing of the mission's primary and

secondary targets (see Table 4), the two instructor SMEs were able to jointly score the mission based on the number and type of targets destroyed by the subject teams.

As discussed earlier, this process was enhanced by the fact that the assigned primary and secondary targets could only be destroyed by the MTS. An important aspect of these scoring procedures was that the two SMEs compared the results from both digital recordings -- one from the lead aircraft and the other from the wing. If the two aircraft were widely separated from one another during the mission, it was possible for one recording to list an assigned target as destroyed while no mention was made of it on the second recording. By comparing the time the targets were destroyed, as they appeared on the digital recording, the SMEs were able to quickly resolve any contradictions and calculate the MTS's mission scores.

Applying the target values from a previously developed scoring table (see Table 16), instructors were able to quickly calculate an overall performance score for the two-dyad MTS. As can be seen in Table 16, if one aircraft within the MTS survived, but was damaged, while the other team was undamaged, the MTS received 50 points. If the team destroyed four of their eight assigned targets, they received 80 points. If they also destroyed three of the seven secondary targets, they gained another 30 points. Finally, if members of the MTS also destroyed two neutral targets, they would lose 80 points. Based on these point totals, this MTS's overall performance score would be 80 points (i.e., 50 + 80 + 30 - 80). These summed inputs provided the information for the mission debriefs and the MTS performance data needed to test the hypotheses described in this study.

Chapter 5

RESULTS

Descriptive statistics and intercorrelations for all the predictor variables used to test the hypothesized model described earlier (see Fig 2) are reported in Tables 17 and 18, respectively. As described earlier, a 2 (complexity) x 3 (training and control) x 3 (time) mixed model ANOVA was conducted to verify that time was not a significant factor in the analysis. Results of this previous analysis (see Table 5) indicated that neither mission order nor timing significantly influenced MTS performance.

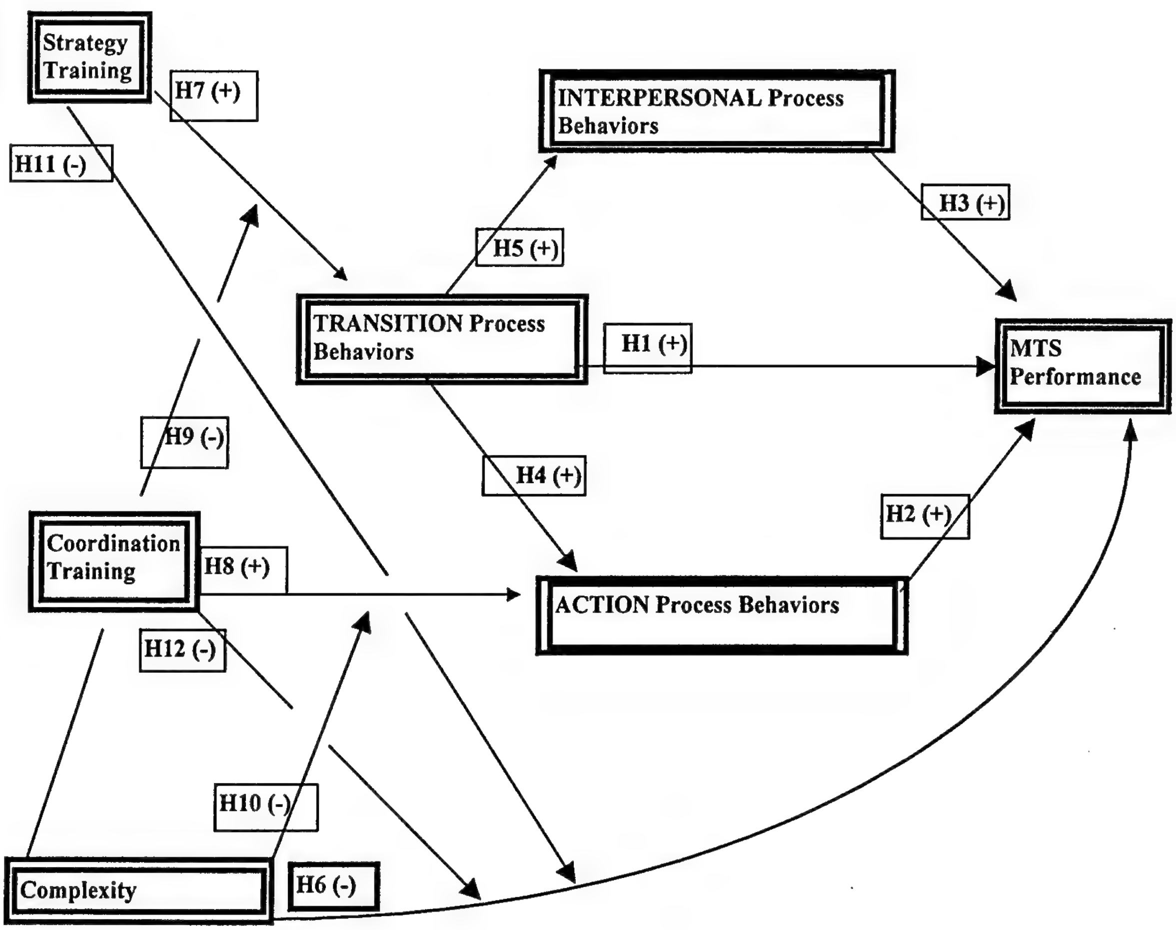
Repeated measures multiple regression (RMMR) analyses were used to test the relationships presented in the hypothesized model. Unlike traditional regression techniques, repeated measures multiple regression allows for the distribution of variance among within and between team variables (Cobb, 1997; Goodwin, 1997; Gully, 1994; Heffner, 1996). This adjusts the F values depending on whether the variable occurs within or between subjects. These adjustments minimize the overestimation of between subjects effects and the underestimation of within subjects effects normally associated with repeated measures regressions (see Cohen & Cohen, 1983; Gully, 1994; Heffner, 1996).

In this study, the input variables, environmental complexity and two training conditions (i.e., strategy and coordination), were between team variables. MTS performance (i.e., outcome) and the three process variables, i.e. interpersonal, action, and transition, were within team variables. Unless otherwise specified, all analyses used to test the hypothesized model occurred at the MTS level. Therefore, teams in this analysis refer to the MTSs discussed earlier, i.e. two interdependent dyads, rather than single dyads comprised of two individuals. RMMR provides a powerful tool to examine the unique variance contributed by

the variables measured in this study.

Model Tests.

To test the hypotheses included in the prescribed model, it was necessary to create a stacked data set containing process and performance data from all appropriate sources. Although this procedure commonly results in a loss of independence between variables, Cohen and Cohen (1983) and Gully (1994) recommend adjusting the F values to compensate. Using RMMR, these adjusted F values were used in all subsequent tests of the model and its variables. Figure 2 has been reprinted here to provide an easy reference while reviewing the results of the analysis.



Inherent in the I-P-O framework is the assertion that the effects of input variables on

outcome are mediated by process. The same holds true for the hypotheses proposed in this study. To test for mediation effects, some method for operationalizing mediation must be employed. Based on earlier work by Baron and Kenny (1986), Kenny, Kashy, and Bolger (1997) described a four-step procedure for determining if mediation is present within a specified framework. This procedure was used in this study to test for all mediation effects present in the hypothesized model.

According to Kenny et al. (1997), the first step in the procedure establishes the fact that there is an effect to be mediated. This is accomplished by regressing the outcome variable upon the input variables to determine if the inputs are significantly affecting outcomes. If there is no direct main effect, then mediation is not possible since there isn't anything to mediate. If a direct main effect is found, then one must establish that the independent variable predictor is significantly related to the proposed mediator (i.e., Step 2). This step involves treating the mediator as an outcome variable in the analysis. In the third step, it must be shown that the mediator affects the outcome variable, controlling for the input variables. Again, the outcome variable is regressed upon the mediator variables to determine if any significant relationship exists.

Using the I-P-O framework, the final step described by Kenny et al. (1997) determines if process completely mediates the effects of the input variables. Complete mediation is indicated when the regression of the outcome variable on the input variables, controlling for the mediator's effects, is reduced to non-significance or nearly zero (Kenny et al.). According to the authors, if the first three steps are met, but not the fourth, then partial mediation exists. In this case, the relationship between the predictor variable and the outcome variable is best described as indirect and being conveyed by the moderator. If this

were the case, training could be seen as having an enabling effect upon action process behaviors that enhances overall MTS performance. The hypothesized effects of the two training conditions in this study provide an example of complete mediation.

Following the four-step procedure described by Kenny et al. (1997), a series of ANOVAs was completed to identify any evidence of mediation within the proposed model. As summarized by Table 19, a 2 x 3 x 3 mixed model ANOVA was used to determine if any significant relationship existed between the input variables (i.e., environmental complexity, strategy training, and coordination training) and the outcome variable (i.e., MTS performance). Since MTS performance was measured in three separate observations, time was included in the analysis to examine any possible interactions with the input variables. Based on this analysis, no significant relationship existed between the input variables and the outcome measures used in this study (Table 19). Therefore, the training and complexity manipulations described earlier had no significant direct impact on MTS performance. The hypothesized mediation was not possible since there was no direct relationship to be mediated between the input and outcome variables.

Although there was no basis for expecting a mediation effect between the input and outcome variables, the relationships hypothesized in the proposed model were further examined for evidence of significant direct effects among the variables. Tables 20-22 summarize the results of the ANOVAs examining the potential relationships between the input variables and the three process measures (i.e., interpersonal, action, and transition). This analysis indicated that the input manipulations also failed to have any significant direct effect upon any of the process variables represented in the hypothesized model. The only significant relationships found in this analysis involved a two-way interaction between

complexity and time (F(2, 29) = 6.79, p≤.01) and a three-way interaction between time*complexity*training (F(4, 58) = 2.77, p≤.05) on interpersonal process behaviors.

Based on these results, it appeared that complexity adversely affected interpersonal process behaviors over time (see Table 20). More specifically, subjects in the low complexity condition seemed to improve their interpersonal process behaviors over time while those in the higher condition seemed to fall apart over time (see Tables 23-24). Figures 3-5 illustrate the results summarized by Tables 23-24 for each of the training conditions.

Figure 3: Coordination Training

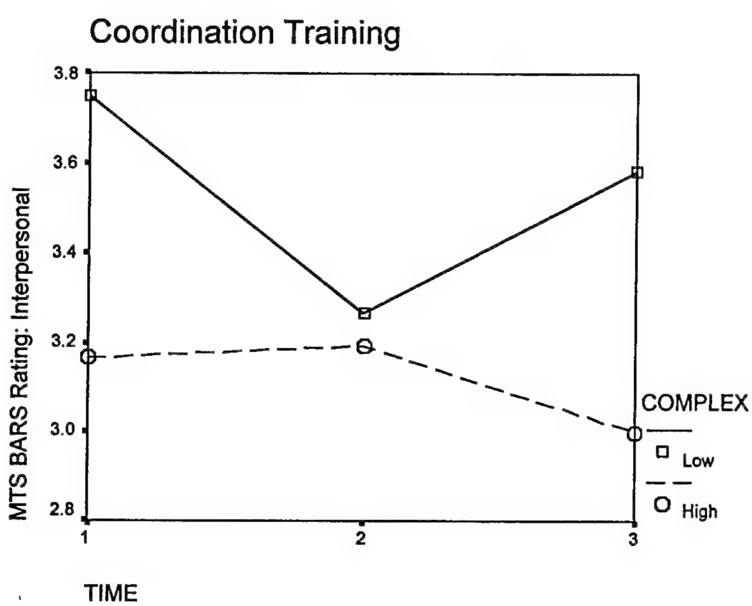


Figure 4: Strategy Training

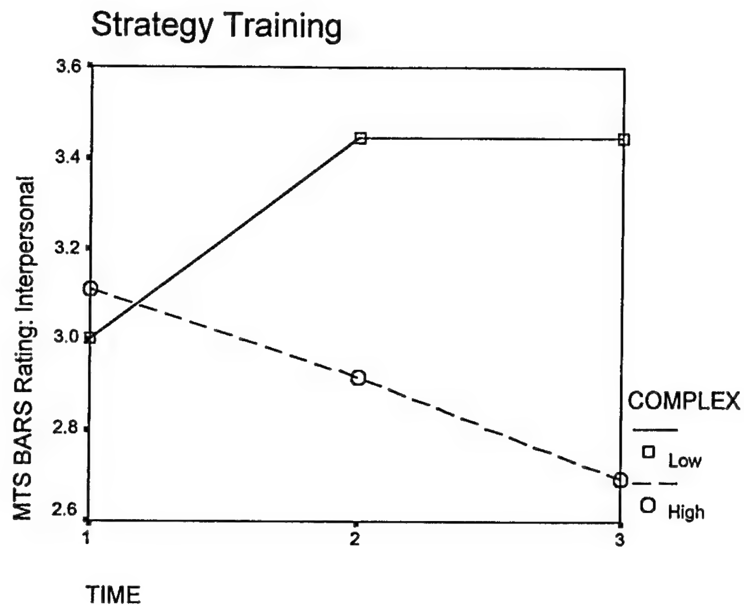
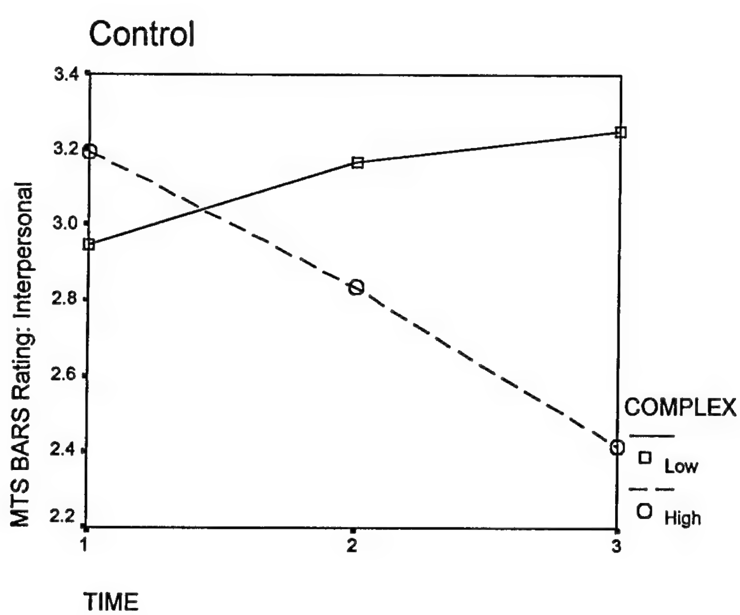


Figure 5: Control Condition



These results were similar to those found in previous studies reviewed by Pelled (1996) and seemed to indicate that the MTS began to experience more interpersonal problems over time under conditions of higher levels of complexity. More complex environments could have increased the amount of negative conflict present within the team,

which adversely affected their interpersonal behaviors (see Pelled, 1996).

The reduction in the quality of the teams' interpersonal from the first to the second mission noted in the low complexity, coordination training condition (see Figure 3) appears to be an aberration, when compared to the other two conditions. Previous research by Gersick (1988, 1989) found that groups tend to pace themselves over time. According to her findings, groups seemed motivated by their awareness of time and deadlines and deliberately shifted their attention at their temporal midpoint. This could apply to teams in the coordination training, since the ROTC teams comprising this condition may have been more concerned about their combined performance score for all three missions, due to the recognition awards used for recruitment, than the undergraduate psychology students in the other conditions or later ROTC teams. This could have contributed to any perceptions they might have had that the three missions were subtasks of a greater whole. Additional data and research is needed to discern if this tendency could have contributed to the pattern of results noted here.

Hypothesized Model. The initial hypotheses, i.e. H1-H3, asserted that effective team processes would be associated with higher levels of MTS performance. Based on Marks et al.'s (in preparation) description, it was believed that how well teams engaged in pre-mission planning, action process behaviors, and interpersonal relations would have direct effects on their performance. As seen in the proposed model, this meant that transition processes should influence overall performance in addition to impacting interpersonal and action process behaviors. Following the sequence of the variables presented in the hypothesized model, interpersonal and action process were entered into the regression equation before transition process and complexity. Appendix K presents a complete summation of the

RMMR results and significance testing for the hypothesized model.

Based on the results from the RMMR, transition and interpersonal process behaviors had no direct main effect on MTS performance (beta = .058, $F(1, 68) = .57$, $p \leq .05$ and -.117, $F(1, 68) = 1.93$, $p \leq .05$, respectively) (see Table 25). Action process behaviors, on the other hand, significantly (beta = .393, $F(1, 68) = 20.44$, $p \leq .01$) impacted how well teams performed in the mission simulations and seemed to carry most of the variance due to team process. Thus, hypothesis 2 was supported by the analysis, while hypotheses 1 and 3 were not.

It was hypothesized that complexity would negatively impact team performance both directly and through team processes (i.e., H6). The data analyzed in this study failed to provide support for this hypothesis. Complexity was not significantly related to MTS performance (beta = -.146, $F(1, 34) = 1.41$, $p > .05$). The hypothesized interactions between complexity and strategy training (i.e., H11) and between complexity and coordination training (i.e., H12) also failed to significantly influence overall team performance (beta = -.062, $F(1, 30) = 0$, $p > .05$; beta = -.464, $F(1,30) = .95$, $p > .05$, respectively) (see Table 25).

The next phase of analysis examined the variable hypothesized to influence MTS interpersonal behaviors. As expected, transition process behaviors directly impacted interpersonal processes (beta = .147, $F(1, 70) = 16.08$, $p \leq .01$) (see Table 26). While hierarchical regression failed to note the significance of this relationship, RMMR analysis corrected the underestimation of within team effects and provided support for the hypothesis (i.e., H5).

Following the proposed model, variables were tested for their influence on MTS action processes. It was hypothesized that the quality of teams' planning strategies (i.e.,

transition process behaviors) would enhance their action process behaviors (i.e., H4). It was also believed that teams receiving coordination training would exhibit more effective action process behaviors (i.e., H8) than those who did not receive such training. Finally, it was hypothesized that environmental complexity would reduce the benefits of coordination training on action process behaviors (i.e., H10).

RMMR analysis indicated that only the first of these hypotheses was supported by the data (see Table 27). Although transition process behaviors were found to significantly affect action process (beta = .26, $F(1, 71) = 14.62$, $p \leq .01$), RMMR analysis showed that coordination training did not significantly influence action process behaviors (beta = .228, $F(1,34) = 3.02$, $p>.05$). The interaction between complexity and coordination training was also found to be an insignificant contributor to action process behaviors (beta = -.542, $F(1, 32) = 1.18$ $p>.05$) (see Table 27).

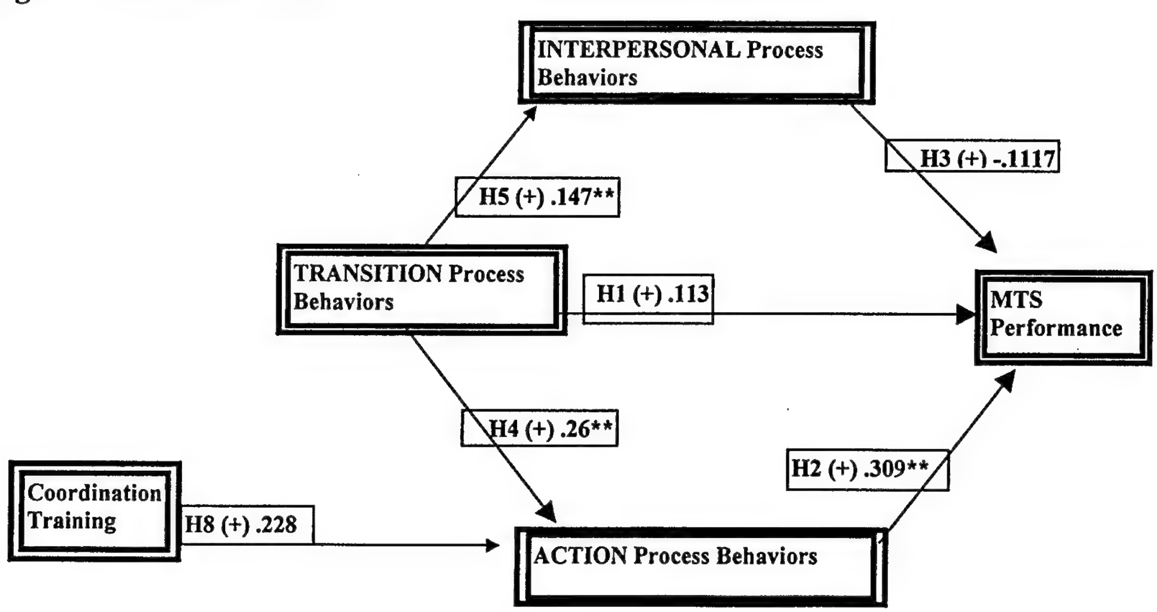
Finally, analyses were conducted to determine if team training significantly contributed to team's transition process behaviors. It was hypothesized that strategy training, which focused on planning and mission analysis behaviors, would significantly enhance teams' transition process behaviors (i.e., H7). RMMR analysis indicated (see Table 28) that there was no support for this hypothesis (beta = -.129, $F(1, 34) = .78$, $p>.05$). In fact, closer examination of the analysis indicated that strategy training might actually negatively influence teams' transition process. It was also hypothesized that the interaction of complexity and strategy training would significantly influence transition process behaviors (i.e., H9). This hypothesis was also unsupported by the RMMR analysis (beta = .701, $F(1, 32) = 1.78$, $p>.05$).

Following the recommendations of Cohen and Cohen (1983), additional regression

analyses were completed to determine if any relationships not represented in the hypothesized model were significant. This was accomplished by first regressing the dependent variable onto those independent variables found as significant in the previous RMMR analyses. Once these variables were entered, stepwise regression was employed to identify any additional significant relationships between the dependent variable and the remaining variables. According to Cohen and Cohen (1983), stepwise regressions are conducted separately from hypothesis testing and define "...a posteriori order based solely on the relative uniqueness of the variables in the sample..." (p. 123). In this way, the number of insignificant relationships can be reduced to increase the chance of identifying previously unrecognized significance levels existing between variables in the hypothesized model. This analysis indicated that no other significant relationships existed in the model.

Trimmed Model. Previous research has found that deleting nonsignificant paths from a model can enhance further tests of relationships that were previously identified as being close to significant levels (e.g., Mathieu, 1988). Based on the previous analysis, the hypothesized model was reduced as seen in Figure 6.

Figure 6: Trimmed Model



While interpersonal and transition process behaviors had been shown earlier as not having any significant effect on MTS performance, they were retained in the trimmed model to see if they gained significance after eliminating complexity from the analysis. This was possible since the previous analyses had shown that subjects had failed to perceive any significant difference between the two complexity conditions. This trimmed model was examined using the same procedures used to test the hypotheses in the original model.

As in the original analysis, the trimmed model was first tested to discover if coordination training's effects on MTS performance were being mediated by action process behaviors, as indicated in Figure 6. Following Kenny et al.'s (1997) recommendations, MTS performance was regressed onto coordination training, controlling for the process variables. As found earlier, the results were not significant (beta = .125, $F(1,34) = 1.12$, $p>.05$), Therefore, there was no evidence supporting mediation of coordination training by action process behaviors.

The remaining hypotheses were tested using RMMR and the results were nearly identical to the original analysis. Of the three process variables, only action process behaviors (beta = .309, $F(1, 68) = 19.21$, $p \leq .01$) directly influenced MTS performance (see Table 29). Transition process behaviors significantly contributed to both interpersonal (beta = .147, $F(1, 70) = 16.08$, $p \leq .01$) and action (beta = .26, $F(1, 71) = 14.62$, $p \leq .01$) process behaviors. Once again, coordination training failed to significantly contribute to action process behaviors (beta = .228, $F(1, 34) = 3.02$; $p>.05$). Subsequent analysis also failed to identify any additional potentially significant relationships in the trimmed model.

Reviewing the results for the original and trimmed model, one additional possibility

became apparent regarding the lack of effects found for transition process behaviors on MTS performance. If transition process behaviors occur before action process behaviors, as represented in the model and described by Marks et al. (in preparation), their direct effects on team performance (i.e., H1) could have been mediated by action process behaviors. Once again, the procedures recommended by Kenny et al. (1997) were used to test this possibility.

First, MTS performance was regressed onto transition process behaviors, controlling for the effects of action process behaviors. RMMR analysis indicated that transition process behaviors significantly contributed to MTS performance (beta = .171, $F(1, 71) = 4.32$, $p \leq .05$) when the effects of action process behaviors were controlled. The previous analysis testing the hypotheses represented in the model established the fact that transition process behaviors direct impacted action process behaviors (step 2 of Kenny et al. (1997)) and action process behaviors impacted MTS performance (step 3). The final step of Kenny et al.'s procedures was completed to determine the level of mediation present in the relationship. According to this analysis, the effects of transition process behaviors on team performance were reduced to insignificance (beta = .058, $F(1, 69) = .61$, $p > .05$) when action process behaviors were entered into the regression. According to Kenny et al., this indicated that the effects of transition process behaviors on MTS performance were completed mediated by action process behaviors.

Employing Continuous Scores for Training Manipulations. To this point in the analysis, dummy codes had been used to identify the appropriate training condition (i.e., coordination, strategy, or control) for the MTS. These dichotomous measures may be too limited to adequately capture the underlying variance in the model due to training conditions. Alternative measures for the training conditions were available in the data. As discussed

earlier, subjects' knowledge of the critical KSAs associated with team strategy and coordination was assessed by three questions used as manipulation checks for the training manipulations.

As earlier analysis indicated (see Table 9), these knowledge measures evidenced the expected mean patterns corresponding to the training manipulation, thus demonstrating some construct validity for the intended knowledge states resulting from the training condition. These measures also reflected the fact that the MTSs may differ in how much understanding and mastery they have in each of the areas addressed by the training conditions, regardless of the specific condition they were placed within. Since these measures may better capture the underlying constructs described in the hypothesized model, the analysis was reaccomplished substituting the manipulation check scale scores for the dummy coded training manipulations.

Again following Kenny et al.'s (1997) recommendations, MTS performance was regressed onto transition process behaviors and the three input variables in separate regressions. As found previously, RMMR analysis indicated that transition process behaviors significantly contributed to MTS performance (beta = .171, $F(1, 71) = 4.32$, $p \leq .05$) when the effects of action process behaviors were controlled. The second RMMR analysis indicated that only coordination training significantly impacted MTS performance (beta = .267, $F(1, 32) = 3.37$, $p \leq .05$).

These results provided some initial support for the results found previously and the model's assertions that the effects of coordination training on team performance were mediated by team process. Testing the hypotheses represented in the model fulfilled the requirements of the next two steps of Kenny et al.'s procedures -- verifying that the mediator

was significantly related to outcomes and the input variables. Once these relationships were tested and established, the final step in the procedure was accomplished to see if complete mediation existed. Appendix L presents a complete summation of the RMMR's results and significance testing for the hypothesized model using continuous scale scores as measures of the MTS' knowledge states derived from the training conditions.

As described earlier, the first three hypotheses (i.e. H1-H3) asserted that effective team process behaviors would be associated with higher levels of MTS performance. Following the sequence of the variables presented in the hypothesized model and used in the original analysis, interpersonal and action process were entered into the regression equation before transition process and complexity. As in the original analysis, only H2 was supported by the RMMR. Action process behaviors significantly impacted MTS performance (beta = .393, $F(1, 68) = 20.44$, $p \leq .01$), while transition and interpersonal process behaviors had no direct main effect on performance (beta = .058, $F(1, 68) = .57$, $p > .05$, and -.117, $F(1, 68) = 1.93$, $p > .05$, respectively; see Table 30). Thus, hypotheses 1 and 3 were not supported by the RMMR analysis.

It was hypothesized that complexity would negatively impact team performance both directly and through team processes (i.e., H6). The results of the RMMR indicated that complexity was not significantly related to MTS performance (beta = -.146, $F(1, 34) = 1.14$, $p > .05$). As in the original analysis, the hypothesized interactions between complexity and strategy training (i.e., H11) and between complexity and coordination training (i.e., H12) also failed to significantly influence team performance (beta = .026, $F(1, 30) = 0$ and beta = -.169, $F(1, 30) = .07$, $p > .05$, respectively) (see Table 30).

As found earlier, transition process behaviors directly impacted interpersonal (beta =

.147, $F(1, 70) = 16.08$, $p \leq .01$) and action (beta = .227, $F(1, 71) = 10.07$, $p \leq .01$) (see Tables 31-32) process behaviors. Thus, H4 and H5 were again supported by the RMMR analysis. As discussed earlier, it was also believed that teams receiving coordination training would exhibit more effective action process behaviors (i.e., H8), while environmental complexity would reduce the benefits of this training for action process behaviors (i.e., H10). Although H10 was not supported (beta = .166, $F(1, 32) = 0$) , the RMMR analysis indicated that coordination training had a significant direct effect on action process behaviors (beta = .279, $F(1, 34) = 4.59$, $p \leq .05$) (see Table 32). This effect was not supported in the original analysis using dummy codes to represent training conditions.

Finally, analyses were conducted to determine if strategy training significantly contributed to teams' transition process behaviors (i.e., H7). RMMR analysis indicated (see Table 33) that there was no support for this hypothesis (beta = -.129, $F(1, 34) = 1.01$, $p > .05$). As discussed earlier, it was also hypothesized that the interaction of complexity and strategy training would significantly influence transition process behaviors (i.e., H9). This hypothesis was also unsupported by the RMMR analysis (beta = .078, $F(1, 32) = .13$, $p > .05$).

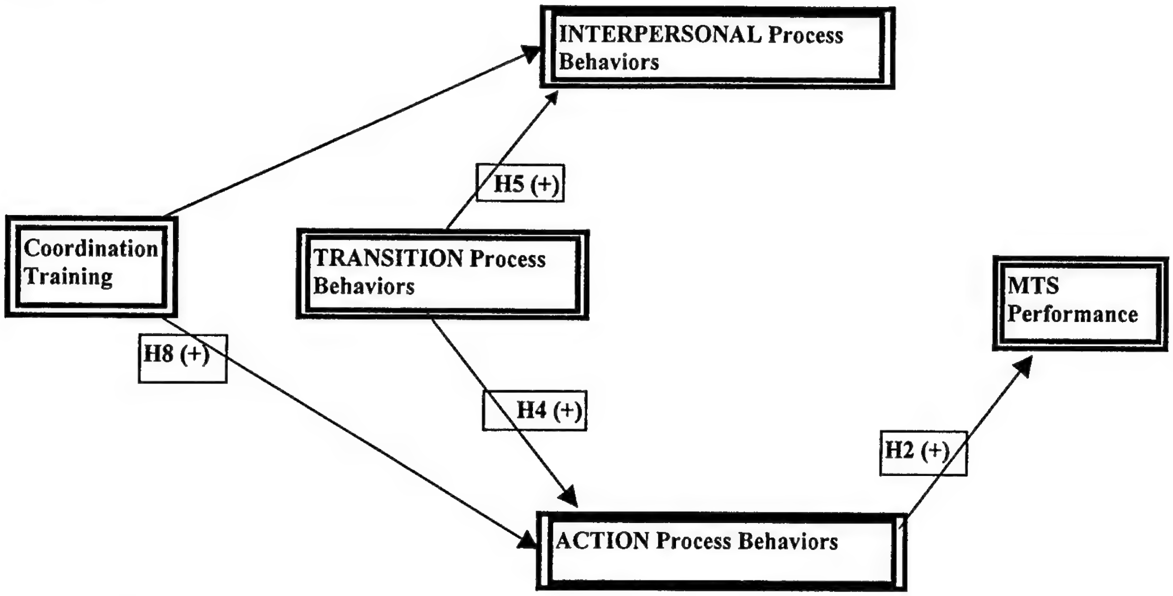
Again, following Cohen and Cohen's (1983) recommendations and the same procedures used in the original analysis, additional regression analyses were completed to determine if any relationships not represented in the hypothesized model were significant. This analysis indicated that coordination training was potentially influencing interpersonal and transition process behaviors. RMMR analyses indicated that there was no significant relationship between coordination training and transition process behaviors (beta = .253, $F(1, 34) = 2.09$, $p > .05$). However, these analyses did indicate that coordination training directly affected interpersonal process behaviors (beta = .324, $F(1, 34) = 4.25$; $p \leq .05$) in addition to

its impact on action process behaviors.

These final tests of the hypothesized model also completed steps two and three of Kenny et al.'s (1997) check for mediation. As discussed earlier in this analysis, not only was coordination training significantly related to MTS performance, controlling for the process mediators, but it was also directly related to two process variables (i.e., interpersonal and action process behaviors). However, step 3 of these procedures required the mediators to significantly affect the outcome variable (i.e., MTS Performance) (Kenny et al., 1997). As discussed earlier, only action process significantly contributed to team performance. RMMR analysis indicated that when action process behaviors were entered into the regression, coordination training completely lost its previous significance (from beta = .236, $F(1, 32) = 4.27$, $p \leq .05$; to beta = .108, $F(1, 32) = .83$, $p > .05$). Therefore, the effects of coordination training on team performance were completely mediated by action process behaviors.

As expected, since none of the original values were altered, the results from the RMMR analysis were identical to those found previously regarding the tests for mediation between action and transition process behaviors. Action process behaviors completely mediated the effects of transition process onto MTS performance. Figure 7 summarizes the findings from this analysis.

Figure 7: Analysis Summary



Exploratory Analysis.

Although some basic exploratory analysis had already been accomplished in testing the hypotheses and mediations represented in the proposed model, several questions remained. One of these focused on the nature of the measure used to indicate the quality of the MTS' transition process behaviors in the original hypothesis testing. As described earlier, this measure was aggregated from SME interview ratings, in-basket exercise scores, and the appropriateness of the teams' weapon selection. Since the interview components of this composite score represented the team leader's summation of the entire planning session, it was thought that they might provide an alternative to the existing composite measure. To test whether this was true, the original hypotheses were retested using the mean of the SME ratings from the mission commander interviews as the transition process behaviors measure.

Following the same procedures used to originally test the proposed model, each of the proposed hypotheses was reexamined using RMMR analysis. The results of these analyses are summarized in Appendix M. As can be seen by comparing the original tests of the

hypothesized model with those using the aggregated interview ratings as the transition process measure (i.e., Appendix K with Appendix M), these results showed some differences from the original analysis. While the retest largely duplicated the original results, it failed to identify any mediation effects or additional areas of significance (see Tables 34 – 37).

Based on these analyses, neither the training or complexity manipulations had any significant effect on MTS performance or team process (see Tables 34 -37). Action process behaviors remained the only significant contributor to team performance (beta = .404, $F(1, 68) = 21.04$, $p \leq .01$) (see Table 34). Unlike the previous two tests of the model, transition process behaviors did not have any significant direct effect on team performance, when action process behaviors were controlled in the analysis (beta = .149, $F(1, 70) = 3.23$, $p > .05$). Therefore, there was no evidence of any mediation in the proposed model when interview scores alone were used as measures of transition process. Transition process behaviors were found to directly impact both interpersonal (beta = .149, $F(1, 68) = 16.08$, $p \leq .01$) and action (beta = .26, $F(1, 71) = 14.35$, $p \leq .01$) process behaviors (see Tables 35 - 36).

Chapter 6

DISCUSSION

The purpose of this study was to expand on previous research examining how manipulating the level of environmental complexity influence MTS process behaviors and performance outcomes. It also tested critical aspects of a new team process framework being developed by Marks et al. (in preparation) and offers insights into potential modifications of the existing model. Specifically it focused on assessing how subject teams performed in a dynamic environment that not only required cooperative behavior between individuals within a single team, but also collective actions between separate teams to achieve assigned performance goals. The results from this study contribute to the body of work supporting and guiding the emerging theory of MTSs. It also expands current research employing low-fidelity personal computer (PC) flight simulations to study team processes and performance (e.g., Goodwin, 1997; Mathieu & Goodwin, 1997; Stout, Cannon-Bowers, Salas, & Morgan, 1990; Kozlowski & Gully, 1996) into the multi-team environment.

The results of this study, as summarized in Table 37, partially support key aspects of the hypothesized framework by shedding light on the nature of the relationships between team process variables. Key among these findings was support for sequencing the process variables in a way that recognized the central role played by transition process behaviors. Previous research has shown that teams' behaviors change over time as they make decision and engage in problem-solving (see Gersick, 1988). Rather than emphasizing problem-solving in isolation, the model examined in this study places these behaviors in conjunction with the actions required to execute decisions both within and between interdependent teams.

Although previous research has consistently illustrated a lack of a strong relationship between interpersonal process behaviors and team performance (see Cannon-Bowers et al., 1995; Driskell & Salas, 1992), findings have been inconsistent in identifying what factors link these behaviors to more action oriented activities. The analyses in this study indicate that transition behaviors, as described by Marks et al. (in preparation), may provide such a link between interpersonal and action process behaviors.

Based on the results of this study, transition process behaviors could be viewed as important enabling activities that enhance other important process behaviors within the team setting. By understanding how their teams' actions are impacted by and influence the actions of other teams, teams within an MTS appear better able to carry out their plans of action to achieve task objectives (see Marks et al., in preparation). Expanding on this theoretical foundation, the results from this study indicate that the primary role of transition process behaviors does not lie in its direct effect on team performance, which was found to be completely mediated by action process behaviors. Instead, transition process behaviors seem to provide critical links between action and interpersonal processes within MTSs and the teams comprising them. This finding is unique and an important contribution to the literature examining team process and performance.

As anticipated, the effects of both coordination training and transition process behaviors on MTS performance were mediated by action process behaviors. Being well trained or having an accurate plan of action prior to a mission could only directly impact performance if the MTS was able to employ those skills or successfully implement the plans during the mission. As emphasized by previous research (e.g., Mathieu et al., 1996; Swezey & Salas, 1992), the actions teams take greatly influence their subsequent actions and how

well they perform on interdependent tasks. Based on the results of this study, previous planning and training can enhance the effectiveness of a MTS actions by increasing their understanding of the task environment and each team's responsibilities within it. These results also indicate that measures reflecting the distributed and collective knowledge and expertise existing within the MTS are a great deal more effective than merely noting their training condition when analyzing the outcomes of training interventions (c.g., Hollenbeck et al., 1995; Liang, Moreland, & Argote, 1995; Moreland, Argote, & Krishnan, 1997; Weick & Roberts, 1993). Future research is required to discern just how closely transition and action process behaviors must be aligned (or divergent) to enhance overall MTS performance.

Team-based research has frequently relied on subject self-reporting for collecting data to test various hypotheses. Although SME observations and ratings were an important part of the data analyzed in this study, no self-reported data was employed to test the proposed hypotheses. This is a significant departure from previous research and reinforces the assertion that multiple sources of information, i.e. objective and subjective, must be used to adequately capture team processes and performance.

Most surprising and somewhat perplexing is the fact that the results of this study failed to show any significant effects resulting from the manipulation of environmental complexity. As discussed earlier in this paper, Pelled (1986) and others have argued that negative conflict increases in more demanding, complex work environments. In fact, the interactions between time*complexity*training discussed earlier (see Tables 23-24) on interpersonal process seemed to indicate that complexity was impacting team process behaviors. As discussed earlier, the failure of the manipulations could indicate that greater variance was needed between the two conditions before subjects could perceive any

significant differences. The addition of only eight distracters, i.e. a 17% increase over the low complexity condition (see Table 4), may not have been sufficient to alter the subjects' perceptions of the task environment's complexity from the perceptions they formed during training and the practice mission.

Based on informal feedback received during training from participants and SME instructors, most participants found the basic training and practice mission (see Table 10) extremely challenging. Being placed in a single complexity condition could have limited the variance normally associated with manipulations of this type. In a sense, there was no opportunity to compare a single MTS' performance and process behaviors in both low and high complexity conditions. An alternative assessment method could have been used to rate the complexity of the missions. SMEs could have been used to rate the recordings of each mission in terms of their complexity. These ratings might provide a more sensitive measure of complexity than the subjects' perceptions of the mission after completing it. Such an analysis is beyond the scope of this paper, since it would require additional data collection.

One factor that could have impacted the results found in this study concern how subjective assessments of transition process behaviors were conducted. While the objective tests used in this study provided insights into teams' reasoning and planning strategies, subjective SME ratings were important to gaining a full appreciation of the effectiveness of their overall transition processes. One limitation to these ratings was that they were based on an interview with one member of the team in isolation from other team members and the MTS' actions during the experimental simulation. Without having observed the MTS' deliberations during their actual planning session, it could have been difficult to accurately determine if the results of the interview accurately reflected the teams' analysis and planning

or that of a single individual. This could have undermined the effectiveness of the SMEs' efforts to assess important transition behaviors and the possible impact of both training conditions.

At the start of each mission planning session, team leaders were also given a copy of the questions to be used during the interview. It was thought that this was needed to expedite the process and ensure mission commanders remained focused and on schedule during the interview. However, a closer look at the questions used in the interview (see Appendix I) reveals that they can easily serve as an advanced organizer for teams to use in their planning sessions. Although not specific about what actions they need to take, the questions do provide insights into what should be considered in strategic planning. Since every team received these questions prior to each mission planning session, it could have caused the training conditions to become increasingly similar over time and made it more difficult to isolate the effects of one training condition from another.

Finally, each of the training conditions used equivalent presentations, in terms of length and depth, to instruct the subjects in this study. However, such a manipulation may have overlooked the fact that subjects could have required greater depth in one area than the other before they could employ these skills. Given the normal life experiences of most undergraduates, it is probably safe to say that they could have had a higher level of competency in employing coordination skills in a group setting than those associated with strategy formulation and planning. Although the manipulation check provided a basic measure of the knowledge of these concepts following training, they might not be sensitive enough measures to identify varying levels of competency within the teams.

Training on coordination skills could have been easier for most subjects to assimilate

and relate to performance outcomes due to their past experiences (c.g., Lord & Maher, 1991; Moreland, Argote, & Krishnan, 1996; Rulke, & Rau, 1997). Strategy formulation training may have presented subjects with unique information that could not be as easily assimilated as that presented in the coordination training condition in the time provided. A pre-training assessment could have provided some important insights into the subject's of competency and knowledge in these two areas by illustrating just how much the subjects had learned during the training sessions rather. The resulting measure could be a more accurate assessment of the training conditions than either of the two measures employed in this study.

These procedures could be at least partially responsible for the lack of significance demonstrated by the training conditions, especially strategy training, in the analyses. The combined effects of these unintended training opportunities and the lack of variation in complexity levels across experimental missions could have reduced or masked their potential significance in a repeated measures regression. This is especially true if the procedures discussed here contributed to the two training conditions being less distinct from each other than originally designed. Future research is required to discern if this assessment accurately reflects potential confounds in the experimental design.

Limitations.

As with any study conducted in a laboratory setting, there are concerns about the generalizability of its findings. Given the unique nature of MTSs, every effort was made to ensure students were aware that they were part of a greater whole than just their dyad. A number of efforts were made during training to maximize the realism of the experimental conditions, such as designing tasks that required all the team members to interact within and between teams comprising the MTS. As evidenced by the number of informal requests by

many teams to return and fly more missions as a unit, the simulation successfully held their interest and reinforced perceptions of team identity.

As discussed earlier, there were limitations in the way data were collected to test the effects of the experimental manipulations. For example, using ratings based on a single team member's responses to questions, while isolated from the MTS setting, as indices of transition process behaviors may not have been the most effective means to assess those constructs. Such ratings may not adequately reflect the actual interactions and planning behaviors underlying MTS decisions before and during the experimental missions. To accurately capture the nature and quality of an MTS' transition processes may require assessing these behaviors when they are actually occurring and in conditions where all team members are interacting rather relying on a single source summation of the team's decisions.

An obvious, and potentially serious, limitation of this research is the subject population comprising each experimental condition. As can be seen in Table 1, ROTC students were concentrated in the high complexity conditions and comprised the entire sample base for the coordination training condition. This allocation resulted from delays in the availability of experimental conditions at the beginning of the overall research project and the original design of this study.

Based on discussions with the command and cadet staff of the ROTC detachments at the university, it was originally believed that more than enough participants would be available from this population to fill each experimental condition examined in this study. Therefore, placing all subjects into the experimental conditions as they became available appeared to present no threat to later analysis. However, when it later became obvious that there would not be enough MTSs from this population to adequately test the proposed

hypotheses, volunteer subjects from undergraduate psychology courses were used to complete the remaining conditions. As discussed earlier, analysis supported this decision and indicated that there was no significant difference between the two sample populations' performance across the experimental conditions. However, it is conceivable that having all the subjects in one of the two experimental training conditions from a single population sample limited the range of responses in other areas as compared with other samples.

Chapter 7

CONCLUSIONS AND IMPLICATIONS

As discussed earlier, manipulating environmental complexity and training conditions failed to strongly influence MTS processes. However, the results from this study also provided support for reconceptualizing the relationships existing between transition, action, and interpersonal processes. Based on these findings, transition process behaviors provide a critical link between interpersonal and action processes in an MTS. This supports the emerging theory of MTS being developed by Marks et al. (in preparation) and offers some initial clarifications of how these team processes interrelate to enhance overall performance. This contributes to the existing literature on team research since there has been little previous examination of how teams function and interact within MTSs. This study also lends additional support to research advocating the importance of examining team behaviors and actions in more dynamic performance environments (e.g., Goodwin, 1997; Mathieu & Goodwin, 1997; Stout et al., 1990; Kozlowski & Gully, 1996) that reflect how teams and team members function and interact in multi-team environments.

The pattern of results from this study, including the lack of significant findings regarding the manipulations, illustrates the need to better understand the factors underlying MTS processes and performance. These findings point out the importance of determining and accurately sampling the environmental conditions in which MTS processes occur. With this insight, it should be possible to better test the hypothesized relationships examined in this study and begin to conceptualize how MTS processes differ from individual teams operating in less interdependent settings.

From an organizational manager's perspective, there is much to be gained by understanding that, just as individuals differ from teams, teams may function quite differently from MTSs. Being able to conceptualize and predict the nature of these differences can greatly enhance the effectiveness of an organization's design and training efforts. Better understanding the unique role transition process apparently plays in the way an MTS functions and performs is an initial step in this effort. Clearly more descriptive and theoretical research is needed to refine these differences and identify their significance to organizational work performance and MTS training.

The results of this study also indicates that training in coordination behaviors, emphasizing teamwork skills, increases MTS performance by enhancing important action process behaviors. These teamwork skills may be as important, or even more so, at the MTS level than has been shown by previous research examining single teams' processes (e.g., Cannon-Bowers et al., 1995; Salas et al., 1992; Stout et al., 1997). Based on the results reported in this paper, organizational managers and training designers should ensure their training programs adequately address the coordination skills demanded by MTSs of the individuals and teams comprising them.

This study builds on existing research examining the impact of environmental complexity on individual (see Wood, 1986) and team (e.g., Cobb, 1998; Elliott et al., 1997; Foushee, 1987) performance by attempting to directly manipulate the complexity of a multi-team task environment. The multi-team nature of this study provided a unique opportunity to explore team performance and processes under conditions approaching the complexity found in normal team task environments. Unfortunately, unlike normal work environments, teams in this study were exposed to relatively consistent levels of environmental complexity that

may have prevented an adequate test of the hypotheses examine in this study. Increasing the differences in the degree of complexity between the conditions should provide a better test of the hypotheses proposed in this study.

From a descriptive standpoint, the results of this study still implied, despite its limitations, that environmental complexity seems to have some differing effects on MTS interpersonal process behaviors based on the nature of teams' previous training experiences. With additional research, it may be possible to better assess these relationships and inform training designers how to best select and design differing training programs for MTSs operating in complex task environments. Additional work is also required to adequately assess the significance of this implication for MTS performance in applied settings and future research.

Future Research.

As is the case with many research efforts, this study has probably raised more questions than providing answers to existing concerns. Because this study represents some initial research into MTS processes and performance, there are a number of challenging and interesting directions for future research. The most pressing need is for additional research to empirically clarify theoretical conceptualizations and relationships. This is needed to better understand how MTSs may differ from smaller, individual teams and how these differences may impact experimental designs and organizational approaches to MTS design.

One obvious area where future research could build on the findings of this study concerns refining the techniques used here to manipulate and assess complexity conditions. Based on previous research (cf., Cobb, 1998; Foushee, 1987; Swezey & Salas, 1992), there may be much to be gained by increasing the variance between the levels of environmental

complexity in which teams operate. Such a design should enhance researchers' ability to detect and assess the effects of differing degrees of environmental complexity on MTS processes and performance. An interesting aspect of this effort for future research is to examine the varying tolerances teams have for increasing complexity over time. A better understanding of how these thresholds originate and are maintained (or altered) within the MTS would greatly enhance future examinations of the effects of environmental complexity and identification of the techniques best suited to control them.

Based on the results from this study, future research should consider using more finely grained assessments of MTS process behaviors to adequately test theorized relationships between constructs. One approach that should be considered was developed by Fowlkes et al. (1995) and focuses on how teams react to particular events, especially unexpected events, during their task performance. The Targeted Acceptable Responses to Generated Events or Tasks (TARGETs) methodology allows an assessment of how well teams confront dynamic circumstances (Fowlkes et al.). This technique has been shown to reduce or overcome such traditional rating errors as halo effects, while remaining sensitive to the fact that different teams may handle the exact same situation using very different performance strategies (Dwyer et al., 1997; Dwyer, Oser, Salas, & Fowlkes, 1999). While these techniques should still be augmented by the continued use of behaviorally based SME ratings (see Dickinson & McIntyre, 1997), the TARGETs approach can provide a richer assessment of team dynamics within the MTS than might otherwise be possible.

Based on the results of this study, interviewing individual team leaders to assess the quality of the MTS' transition processes may not be able to fully capture the richness of this important construct. One technique that could be employed by future research would be to

examine these behaviors as they occur during the pre-task planning. Video taping these planning sessions would not only provide a record for later comparisons and analysis, but could also enhance evaluations of emerging team leadership, conflict management, and the effectiveness of team training within the MTS.

While it could be difficult at times to discriminate activities that provide evidence for effective transition behaviors and those more aligned to action or interpersonal process, the resulting data base could give a better researchers a richer means to assess the quality of MTS' transition processes than relying on one subject's summation of the teams' intentions. To enhance the richness of the interview, future researchers employing the simulation used in this study should also consider conducting it in the presence of the entire MTS. Using videotaped recordings, frequency measures of the MTS member's reactions to and corrections of the mission commander's responses could enhance the quality of the assessment and the data available for later analysis.

Finally, subjective ratings should be conducted and analyzed at both the team and MTS level. Based on the results of this study, there may be large differences between the processes demonstrated by individual teams versus those exhibited by the MTS. For example, both individual teams may be demonstrating a high level of team process as they accomplish their assigned objectives, yet not interacting at the MTS level to any significant degree.

In this study, it was possible, despite embedded penalties for doing so, for the two dyads to split apart at the start of the mission and not rejoin at any point during the mission nor coordinate any of their activities. If both dyads performed and interacted well, even in self-imposed isolation for each other, the aggregated SME ratings would not be indicative of

the quality (or lack of it) of the larger MTS' processes. Additional recordings of the experimental session could be used to minimize halo effects resulting from previous ratings at the individual and dyad level.

Some consideration should also be given by future research using this simulation to conducting a separate analysis of the two dyads, i.e. wing and lead aircraft. Researchers could closely examine how the behaviors and performance of each of these two subteams separately affects MTS performance. This analysis could highlight significant differences between the two dyads and possibly provide findings that might go otherwise undetected.

Conclusions.

This research illustrates the importance of transition processes in MTS functioning and performance and thus contributes to a new and growing body of research expanding the team literature into multi-team environments. As organizations continue to increase their reliance on teams to accomplish their goals and objectives, more and more teams will find themselves in environments where their success depends on how well they orchestrate their collective actions within a larger structure, i.e. the MTS. The current research also implied that training and environmental complexity may potentially influence how well MTSs perform at higher levels of complexity. However, as noted earlier, this study raised many questions that require further research to clarify and understand the external and internal factors impacting MTS process and performance.

NOTES

[1] This is the lowest rank for officers in the US Air Force, while Master Sergeant is a senior ranking Noncomissioned Officer (NCO) among enlisted personnel.
[2] Although the teams would be given limited training and resources for conducting air-to-air combat, their assigned tasks in each experimental mission was to identity and destroy selected ground targets.
[3] CRM emerged from civilian and military efforts to reduce flying errors and aviation accidents by improving team process early in a team's formation (Cavanagh & Williams, 1987; Foushee, 1987; Prince & Salas, 1993). Air Crew Training (ACT) refers to the various military versions of this type of training (Guzzo & Dickson, 1996). Due to differing command relationships, missions, and policies, there is not presently a uniform version of CRM embraced by all military services.
[4] Students enrolled in the USAF and US Army ROTC programs are referred to as cadets. Students in the US Navy, including the US Marine option, are referred to as midshipmen. These designations are identical to those used at the military academies.
[5] An USAF ROTC cadet flight is a hierarchical structure within the organization containing about 16-28 cadets.
[6] The author of this study is a senior USAF officer and has over 10 years of operational experience in multiple weapons systems designing training mission simulations. Additionally, the USAF ROTC detachment commander was consulted for his expertise on flight and combat operations. He is a senior USAF officer with extensive operational and command experience in three different combat aircraft. Before his present assignment, he was the Vice Commander of the 48th Fighter Wing, Royal Air Force Lakenheath, England. This unit flies our most advanced tactical fighter, the F-15C, and routinely engages in allied operations.
7 "TAW is probably the finest modern USAF flight simulation on the market to depict the tactical and operational level of modern airpower" (Air University, Aerospace Basic Course, 1998).

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Appendix A: Tables

Table 1. Experimental Condition Assignment

TRAINING CONDITION	COMPLEXITY LEVEL	TEAM SUBJECT POPULATION COMPOSITION
Strategy	Low	2 - ROTC (1 - AFROTC; 1 - NROTC) 4 - Psychology
	High	4 - ROTC (3 - AFROTC; 1 - NROTC) 2 - Psychology
Coordination	Low	6 - ROTC
	High	6 - ROTC (4 - AFROTC; 1 - Army ROTC; 1-NROTC)
Control	Low	2 - ROTC (1 - AFROTC; 1 - NROTC) 4 - Psychology
	High	3 - ROTC (2 - AFROTC; 1 - Army ROTC) 2 - Psychology 1 - Other (Gaming Association)

Note: Each team listed successfully completed all three experimental missions in the time allowed.

Table 2. Participant Demographics

SEX

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	99	68.8	71.7	71.7
	Female	39	27.1	28.3	100.0
	Total	138	95.8	100.0	
Missing	System	6	4.2		
Total		144	100.0		

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18	33	22.9	23.9	23.9
	19	28	19.4	20.3	44.2
	20	28	19.4	20.3	64.5
	21	24	16.7	17.4	81.9
	22	17	11.8	12.3	94.2
	23	3	2.1	2.2	96.4
	24	3	2.1	2.2	98.6
	30	1	.7	.7	99.3
	31	1	.7	.7	100.0
	Total	138	95.8	100.0	
Missing	System	6	4.2		
Total		144	100.0		

ethnicity

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	caucasian/white	114	79.2	82.6	82.6
	African American/Black	7	4.9	5.1	87.7
	Hispanic	6	4.2	4.3	92.0
	Asian American	10	6.9	7.2	99.3
	Other	1	.7	.7	100.0
	Total	138	95.8	100.0	
Missing	System	6	4.2		
Total		144	100.0		

Table 3. Task Functions Critical to Performance by Position

Function	Pilot	Weapon Specialist
select HUD displays (e.g., air-to-air, air-to-ground, navigation)	A	X
control pilot head movement/views	X	N/A
pull up pilot aids (radar displays)	A	X
interpret pilot aids: radar display	X	A
interpret pilot aids: waypoint display	A	X
fly/maneuver the plane	X	N/A
control plane orientation in relation to the horizon	X	A
track waypoints	A	X
select/cycle waypoints	A	X
track mission timing	A	X
control manual emcom settings	A	X
control airspeed	X	A
control airbrakes	X	N/A
control altitude	X	A
control communication switchboard	A	X
control communication as the spokesperson	A	X
decision to communicate to other flight team	A	X
create shoot lists	A	X
control weapon selection	A	X
fire weapons	X	A
determine enemy position (e.g., distance, altitude, and airspeed)	X	X
track # and type of weapons remaining	A	X
detect and evade enemy radar lock	X	X
detect and evade enemy attack (e.g., missile launch, cannon fire, AAA, etc.)	X	X
achieve radar lock on enemy targets	X	X
release defense measures (e.g., chaffs, flares)	A	X
select and cycle enemy targets	A	X

X: pilot or weapons specialist is responsible for carrying out this function
A: pilot or weapons specialist should be aware

Table 4. Targets Listing

MISSION	TARGET TYPES: assigned	TARGET TYPES: bonus	TARGET TYPES: all possible	ADDITIONAL Targets to increase COMPLEXITY
PRACTICE MTS	4/9 T-80 tanks 3 mobile AAA 1 mobile SAM (Crotale) **Total: 8**	5 T-80 tanks 2 bedford trucks **Total: 7**	6 M-1 tanks (friendly) 7 G-6 SPGs 9 T-80 tanks 3 mobile AAA 5 humvees (friendly) 2 mobile SAMs (SA-11) 1 mobile SAM (Crotale) 7 fuel trucks 2 bedford trucks 4 SU-27s **Total: 46**	
RIDGE JUMPER	4/6 T-80 tanks 2 fuel trucks 2 mobile SAMs (Crotale) **Total: 8**	2 T-80 Tanks 5 bedford trucks **Total: 7**	6 M-1 tanks (friendly) 6 G-6 SPGs 4 mobile AAA 6 T-80 tanks 4 AH64 Apaches (friendly) 1 Boeing C767 (neutral) 5 bedford trucks 10 humvees (friendly) 2 fuel trucks 2 mobile SAMs (SA-11) **Total: 46**	1 AAA 4 SPGs 3 fire trucks **New Total: 54**
RIVER RUN	2 mobile AAA 2/4 hovercraft 4/6 T-80 tanks **Total: 8**	2 hovercraft 2 T-80 tanks 3 bedford trucks **Total: 7**	2 mobile SAMs (SA-11) 2 mobile AAA 4 hovercraft 15 M-1 tanks (friendly) 4 Humvees (friendly) 2 passenger ferries (friendly) 4 MiG-21s 6 T-80 tanks 3 bedford trucks 4 SU-27s **Total: 46**	2 fire trucks 2 gun boats 4 SPGs **New Total: 54**
CANYON SWEEP	5 mobile AAA 3 mobile SAMs (Crotale) **Total: 8**	7 Bedford trucks **Total: 7**	1 Mig-21 2 IL-76 transports 5 mobile AAA 3 mobile SAMs (Crotale) 6 M-1 tanks (friendly) 9 T-80 tanks 3 MI24 HIND helicopters 2 SU-27s 7 bedford trucks 3 Humvees (friendly) 2 Limos (Neutral) 1 fire truck (Neutral) 2 fuel trucks **Total: 46**	4 T-80 tanks 4 SPGs **New Total: 54**

Table 5. ANOVA Summary Table -- Potential Mission Order and Timing Effects

	T1	T2	T3	F (2, 33)
Ridge Jumper	Mean = 95.83 SD = 72.80 N = 12	Mean = 134.17 SD = 79.25 N = 12	Mean = 117.50 SD = 70.81 N = 12	.88 n.s.
River Run	Mean = 113.08 SD = 50.56 N = 13	Mean = 112.73 SD = 66.04 N = 11	Mean = 105.83 SD = 69.73 N = 12	.95 n.s.
Canyon Sweep	Mean = 158.18 SD = 60.14 N = 11	Mean = 120.00 SD = 78.21 N = 13	Mean = 110.83 SD = 58.69 N = 12	.621 n.s.
F (2, 33)	3.12 n.s.	.78 n.s.	.104 n.s.	

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 6. Task Training

Subject	Task Areas
Basic Maneuvering	Communicating within teams Maintaining flight Climbing and Diving Turning aircraft and leveling flight Controlling speed Air braking Changing cockpit views Recovering from stalls Avoiding crashing into the ground Interpreting the heads-up display (HUD) Determining flight altitude Determining air speed Interpreting the horizon display
Navigating Flight Routes	Following flight plans Identifying and tracking waypoints Identifying aircraft types
Basic Air-to-Air (AA) Combat	Interpreting AA HUD information displays Identifying enemy targets Identifying friendly aircraft Changing EMCOM settings Releasing chaffs and flares Selecting AA weapons Targeting enemy aircraft Firing weapons Evading enemy missile lock and attack Identify indications of successful attacks on enemy targets
Basic Air-to-Ground (AG) Combat	Interpreting AG HUD displays Identifying enemy ground targets Identifying friendly ground forces Selecting AG weapons Targeting ground targets Firing weapons Identify indications of successful attacks on enemy targets
Practice Multiteam Simulation (MTS)	Communicating between wing and lead aircraft Identifying and tracking "partner" aircraft Identify role of mission commander Refine previous flight and combat skills

Table 7. Task Training Competencies Checklist

Basic Aircraft Maneuvering Competencies:
Subjects should be able to:

1. climb. ☐
2. dive. ☐
3. accelerate. ☐
4. break. ☐
5. turn. ☐
6. recover from a stall. ☐
7. look around (using the joystick). ☐
8. ascertain their altitude. ☐
9. identify their speed. ☐
10. determine and control their angle of ascent/descent. ☐

Navigating a Flight Route Competencies.
Subjects should be able to:

1. Follow a preplanned flight path. ☐
2. Change waypoints (advance/move back). ☐
3. Activate and interpret pilot aids displays ☐
4. Increase/decrease range of pilot aids. ☐
5. Switch HUDs. ☐
6. Identify current HUD and interpret display. ☐
7. Change EMCOM levels. ☐
8. Identify stealthiness of EMCOM levels. ☐

Basic Air-to-Ground Competencies
Subjects should be able to:

1. Identify and select enemy ground targets. ☐
   a. identify their range to target. ☐
   b. on the infrared display. ☐
   c. on the HUD. ☐
   d. identify SAMS. ☐
   e. identify targets added to shoot list. ☐
2. Choose appropriate weapons. ☐
3. Determine the number of available weapons. ☐
4. Fire weapons. ☐
5. Add targets to shoot lists. ☐
6. Cycle targets. ☐
7. Evade enemy missiles (including flares and chaff). ☐

Basic Air-to-Air Competencies
Subjects should be able to:

1. Identify and select enemy air targets. ☐
   a. their range to the target. ☐
   b. identify a targeted enemy plane. ☐
   c. cycle targets ☐
2. Identify and select the appropriate weapon to be used. ☐
3. Identify the number of available weapons. ☐
4. Evade enemy missiles (including flares and chaff). ☐

Table 8. Team Training SME Ratings

Descriptive Statistics

Correlations (N = 228)

		TEAMTR1A	TEAMTR2A	TEAMTR3A	TEAMTR1B	TEAMTR2B	TEAMTR3B
TEAMTR1A	Pearson Corr	1.000					
	Sig. (2-tailed)	.					
TEAMTR2A	Pearson Corr	-.112	1.000				
	Sig. (2-tailed)	.091	.				
TEAMTR3A	Pearson Corr	-.101	-.167	1.000			
	Sig. (2-tailed)	.129	.012	.			
TEAMTR1B	Pearson Corr	.650**	-.171**	-.111	1.000		
	Sig. (2-tailed)	.000	.010	.096	.		
TEAMTR2B	Pearson Corr	-.140*	.766**	-.208**	-.116	1.000	
	Sig. (2-tailed)	.035	.000	.002	.081	.	
TEAMTR3B	Pearson Corr	-.132*	-.182**	.727**	-.107	-.160*	1.000
	Sig. (2-tailed)	.047	.006	.000	.108	.015	.

** Corr is significant at the 0.01 level (2-tailed).
* Corr is significant at the 0.05 level (2-tailed).

Key:
TEAMTR1A: Rater 1 assessment of coordination training knowledge
TEAMTR2A: Rater 1 assessment of strategy training knowledge
TEAMTR3A: Rater 1 assessment of interpersonal training knowledge
TEAMTR1B: Rater 2 assessment of coordination training knowledge
TEAMTR2B: Rater 2 assessment of strategy training knowledge
TEAMTR3B: Rater 2 assessment of interpersonal training knowledge

Table 9. Team Training Manipulation Checks

Test Items →	Coordination	Strategy	Task Knowledge
Training Condition			
Coordination **Mean**	1.41a	.65b	9.54
Std Dev	.69	.44	.65
Strategy **Mean**	.49b	1.75a	9.58
Std Dev	.37	.76	.71
Control **Mean**	.76b	.60b	9.40
Std Dev	.40	.43	.84
F (ANOVA)	41.71**	63.46**	.85 n.s.

**indicates $p \leq .01$

Table 10. ANOVA Summary Table -- Environmental Complexity

	df	Error df	F
Linear Effects			
Within			
Time	2	276	.678
Between			
Complexity	1	138	.059
Training	2	138	2.817
Two-Way Interactions			
Within			
Time x Complexity	2	276	.448
Time x Training	4	276	.431
Between			
Complexity x Training	2	138	.519
Three-Way Interaction			
Within			
Time x Complexity x Training	4	276	2.414 *

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 11. MTS MISSION SCHEDULE

MTS ID	Training Condition	Mission Order	Complexity
1 (ROTC)	Coordination	RJ, RR, CS	Low
2 (ROTC)	Coordination	CS, RR, RJ	Low
3 (ROTC)	Coordination	RR, RJ, CS	Low
4 (ROTC)	Coordination	RJ, CS, RR	Low
5 (ROTC)	Coordination	RR, CS, RJ	Low
6 (ROTC)	Coordination	CS, RJ, RR	Low
25 (ROTC)	Coordination	RJ, RR, CS	High
26 (ROTC)	Coordination	CS, RR, RJ	High
13 (ROTC)	Coordination	RR, RJ, CS	High
14 (ROTC)	Coordination	RJ, CS, RR	High
11 (ROTC)	Coordination	RR, CS, RJ	High
12 (ROTC)	Coordination	CS, RJ, RR	High
9 (ROTC)	Strategy	RJ, RR, CS	Low
10 (ROTC)	Strategy	CS, RR, RJ	Low
21 (Psyc)	Strategy	RR, CS, RJ	Low
22 (Psyc)	Strategy	RJ, CS, RR	Low
26 (Psyc)	Strategy	RR, CS, RJ	Low
18 (Psyc)	Strategy	CS, RJ, RR	Low
27 (Psyc)	Strategy	RJ, RR, CS	High
20 (ROTC)	Strategy	CS, RR, RJ	High
21 (ROTC)	Strategy	RR, RJ, CS	High
22 (ROTC)	Strategy	RJ, CS, RR	High
23 (ROTC)	Strategy	RR, CS, RJ	High
32 (Psyc)	Strategy	CS, RJ, RR	High
7 (ROTC)	Control	RJ, RR, CS	Low
8 (ROTC)	Control	CS, RR, RJ	Low
12 (Psyc)	Control	RR, RJ, CS	Low
25 (Psyc)	Control	RJ, CS, RR	Low
13 (Psyc)	Control	RR, RJ, CS	Low
11 (Psyc)	Control	RJ, RR, CS	Low
31 (ROTC)	Control	RJ, RR, CS	High
32 (ROTC)	Control	CS, RR, RJ	High
33(ROTC)	Control	RR, RJ, CS	High
34 (Game)*	Control	RJ, CS, RR	High
30 (Psyc)	Control	RR, CS, RJ	High
31 (Psyc)	Control	CS, RJ, RR	High

*This team was comprised of members of an on-campus gaming association. For purposes of this study, they were treated as a ROTC MTS during all analyses.

Table 12. Operational Team Process Definitions

Team Process Dimension	Conceptual Definition	Operational Definition for ACES Performance Environment
Mission Analysis	Interpretation and evaluation of the team's mission, including identification of the mission's main tasks as well as the operative environmental conditions and team resources available for mission execution.	Team's attempt to understand the overall MTS mission and their unique contribution to the mission. This would include ensuring that the entire team has a clear understanding of the team's mission, the major components of the mission, and the team resources that are available for the mission.
Goal Specification	Identification and prioritization of goals and subgoals for mission accomplishment.	Develop and assign overall mission goal for MTS. Develop and assign goals for each team in the MTS. Develop and assign subgoals that help teams accomplish larger goals
Strategy Formulation and Planning	Formulation of strategies and courses of action for mission accomplishment. a. *GenericPlanning:* Formulation and transmission of a primary course of action for mission accomplishment. b. *Contingency Planning:* A priori formulation and transmission of alternative plans and strategy adjustments in response to anticipated changes in the performance environment. c. *Reactive Strategic Adjustment:* The alteration of existing strategy or plan in response to unanticipated changes in the performance environment and/or performance feedback.	a. Develop a main plan to take out enemy ground weapons without getting killed. Communicate this plan to team members. b. Consider factors that might interfere with the main plan, such as enemy vehicles or friendly casualties, and develop some alternative plans. c. When team is performing and something unexpected occurs, such as a plane running out of mavericks or that enemies are just spotted to the rear of the aircraft, plans should be adjusted quickly to take into account the new information.
Monitoring Progress Toward Goals	Tracking task and goal progress toward mission accomplishment; interpreting system information in terms of what needs to be accomplished for goal attainment, transmitting team goal progress to team members.	Tracking and reporting team's (teams') progress on goals and subgoals in real time, such as flight routes, enemies killed, friendly casualties, and time.

Table 12. Operational Team Process Definitions (cont.)

Systems Monitoring	Tracking team resources and environmental conditions as they relate to mission accomplishment. a. *Internal Systems Monitoring*: Tracking team resources such as personnel, equipment, and other information that is generated or contained within the team. b. *Environmental Monitoring*: Tracking the environmental conditions relevant to the team.	 a. Tracking team related factors such as weapon availability, speed, fuel, altitude, and radar information; ensuring that these systems are operating effectively. b. Tracking aspects of the aircraft environment such as terrain shifts, enemy locations and strength, and friendly forces.
Team Monitoring and Backup Behavior	Assisting team members to perform their tasks. Assistance may occur by a) providing a teammate verbal feedback or coaching, b) by assisting a teammate behaviorally in carrying out actions, or c) by assuming and completing a task for a teammate. This dimension includes the provision of feedback and task-related support and the seeking of help from teammates when necessary.	Keeping an eye on other teammates to determine if and when they need help. When necessary, helping teammates with their assigned roles by telling them what to do and/or how to do it. When the capability exists, teams/team members may step in and carry out a task for another team/team member.
Coordination Activities	Orchestrating the sequence and timing of interdependent actions.	Organizing how and when team members (and teams) will synchronize actions that require the contribution of both pilot and weapon specialist, or that require the efforts of more than one team in multiteam situations.
Conflict Management	a. *Preemptive Conflict Management:* Establishing conditions to prevent, control, or guide team conflict *before* it occurs. b. *Reactive Conflict Management:* Working through task and interpersonal disagreements among team members.	a. Team member(s) making statements or offering opinions about task related issues, the way the team functions together, or personal issues, that are likely to affect subsequent team conflict. b. When conflict with the team (or between teams) arises, team member(s) efforts to work through the conflict.
Motivating and Confidence Building	Generating and preserving a sense of collective confidence, motivation, and task based cohesion with regard to mission accomplishment.	Team members efforts to motivate each other, influence the level of confidence of team members, and influence the level of task cohesion of team members with respect to the mission at hand.
Affect Management	Regulating member emotions during mission accomplishment, including (but not limited to) social cohesion, frustration, and excitement.	Team members' influence on the positive and negative emotions of other members.

Table 13. Transition Process Measures Correlation Matrix

Correlations

		IMA	IGS	ISFP	WEAP	INTEL	SITREP	QSORT
IMA	Pearson Correlation	1.000	.779**	.769**	.100	.207*	.188*	.255**
	Sig. (2-tailed)	.	.000	.000	.236	.013	.024	.002
	N	143	143	143	143	143	143	143
IGS	Pearson Correlation	.779**	1.000	.774**	.064	.159	.174*	.215**
	Sig. (2-tailed)	.000	.	.000	.446	.058	.037	.010
	N	143	143	143	143	143	143	143
ISFP	Pearson Correlation	.769**	.774**	1.000	.104	.203*	.276**	.310**
	Sig. (2-tailed)	.000	.000	.	.215	.015	.001	.000
	N	143	143	143	143	143	143	143
WEAP	Pearson Correlation	.100	.064	.104	1.000	.245**	.371**	.399**
	Sig. (2-tailed)	.236	.446	.215	.	.003	.000	.000
	N	143	143	143	144	144	144	144
INTEL	Pearson Correlation	.207*	.159	.203*	.245**	1.000	.204*	.762**
	Sig. (2-tailed)	.013	.058	.015	.003	.	.014	.000
	N	143	143	143	144	144	144	144
SITREP	Pearson Correlation	.188*	.174*	.276**	.371**	.204*	1.000	.789**
	Sig. (2-tailed)	.024	.037	.001	.000	.014	.	.000
	N	143	143	143	144	144	144	144
QSORT	Pearson Correlation	.255**	.215**	.310**	.399**	.762**	.789**	1.000
	Sig. (2-tailed)	.002	.010	.000	.000	.000	.000	.
	N	143	143	143	144	144	144	144

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Key:
IMA: mission analysis rating from mission commander interview
KGS: goal specification rating from mission commander interview
ISFP: strategy formulation and planning rating from mission commander interview
WEAP: weapons option selection score
INTEL: score from intelligence reports sort (partial q-sort score)
SITREP: score from situation report sort (partial q-sort score)
QSORT: total score from q-sort exercise

Table 14. Action and Interpersonal Process Measures

Mission	Unrestricted Maximum Likelihood Chi Squared	Action Process $\alpha =$	Interpersonal Process $\alpha =$
T1	27.39**	.82	.83
T2	25.09**	.83	.90
T3	23.76**	.81	.89
	22.63**	.74	.90
Overall →	43.89**	.81	.88

**significant at the 0.01 level

Table 15. Lead and Wing Team Process Ratings Correlation Matrix

BARS Rating:	T1	T2	T3	Overall
Interpersonal Process Behaviors	.208 N = 36	.06 N = 35	.32 N = 36	.20* N = 107
Action Process Behaviors	.45** N = 36	.57** N = 35	.39** N = 36	.45** N = 107

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 16. MTS Performance Scoring

	Description	Point Assessment
Time Alive	The actual duration of each dyad's mission, i.e. how long did the aircraft survive.	No points awarded. Time recorded for later analysis. Maximum time: 15 minutes
Aircraft Status	The status of each aircraft at the mission's conclusion. Summed to MTS team level.	Undamaged = 30 points/aircraft Damaged = 20 points/aircraft Destroyed = 0 points/aircraft Range = 0 to 60
Target Types – Assigned	Indicates how many of the assigned (i.e., primary) mission targets the MTS team destroyed.	20 points/assigned target Range = 0 to 160
Target Types – Bonus	Indicates how many of the bonus (i.e., secondary) mission targets the MTS team destroyed.	10 points/bonus target Range = 0 to 70
Penalty Deduction	Indicates how many neutral targets the MTS team destroyed. Points deducted from total.	- 40 points/target Range = -120 to 0
Total Mission Score	Summation of all MTS team scores and deductions.	Range = -120 to 290

Table 17. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
ACTION PROCESS	108	1.00	4.63	3.1424	.6896	.476
INTERPERSONAL PROCESS	107	1.50	5.00	3.1308	.7767	.603
MTS PERFORMANCE	108	0	280	118.33	66.40	4408.411
TRANSITION PROCESS	108	-1.27	1.72	.2892	.6790	.461
COORDINATION TRAINING	108	0	1.00	.3333	.4736	.224
STRATEGY TRAINING	108	0	1.00	.3333	.4736	.224
COMPLEX*COORD	108	0	2.00	.50	.7673	.589
COMPLEX*STRATEGY	108	0	2.00	.50	.7673	.589
COMPLEXITY	108	1	2	1.50	.50	.252

Table 18. Correlation Matrix

	Pearson	COMPL	ACTION	INTERP	PERFO	TRANSITI	COORDT	STRATT	COMXCO	COMXST
COMPL	Sig. (2-	.	.665	.013	.174	.558	1.000	1.000	.023	.023
	N	108	108	107	108	108	108	108	108	108
	Pearson	-.042	1.000	.504**	.394**	.299**	.272**	-.093	.193*	-.070
ACTION	Sig. (2-	.665	.	.000	.000	.002	.004	.338	.045	.475
	N	108	108	107	108	108	108	108	108	108
	Pearson	-.239*	.504**	1.000	.125	.147	.178	-.027	.106	-.080
INTERP	Sig. (2-	.013	.000	.	.198	.130	.066	.785	.276	.413
	N	107	107	107	107	107	107	107	107	107
	Pearson	-.132	.394**	.125	1.000	.171	.125	.053	.028	.059
PERFO	Sig. (2-	.174	.000	.198	.	.078	.198	.582	.777	.546
	N	108	108	107	108	108	108	108	108	108
	Pearson	-.057	.299**	.147	.171	1.000	.170	-.129	.123	-.071
TRANSITI	Sig. (2-	.558	.002	.130	.078	.	.078	.183	.203	.465
	N	108	108	107	108	108	108	108	108	108
	Pearson	.000	.272**	.178	.125	.170	1.000	-.500**	.926**	-.463**
COORDT	Sig. (2-	1.000	.004	.066	.198	.078	.	.000	.000	.000
	N	108	108	107	108	108	108	108	108	108
	Pearson	.000	-.093	-.027	.053	-.129	-.500**	1.000	-.463**	.926**
STRATT	Sig. (2-	1.000	.338	.785	.582	.183	.000	.	.000	.000
	N	108	108	107	108	108	108	108	108	108
	Pearson	.218*	.193*	.106	.028	.123	.926**	-.463**	1.000	-.429**
COMXCO	Sig. (2-	.023	.045	.276	.777	.203	.000	.000	.	.000
	N	108	108	107	108	108	108	108	108	108
	Pearson	.218*	-.070	-.080	.059	-.071	-.463**	.926**	-.429**	1.000
COMXST	Sig. (2-	.023	.475	.413	.546	.465	.000	.000	.000	.
	N	108	108	107	108	108	108	108	108	108

* Correlation is significant at the .05 level (2-tailed).
**Correlation is significant at the .01 level (2-tailed).

Table 19. ANOVA Summary Table -- MTS Performance

	df	Error df	F
Linear Effects			
Within			
Time	2	60	.405
Between			
Complexity	1	30	1.290
Training	2	30	1.246
Two-Way Interactions			
Within			
Time x Complexity	2	60	2.254
Time x Training	4	60	1.188
Between			
Complexity x Training	2	30	1.409
Three-Way Interaction			
Within			
Time x Complexity x Training	4	60	.879

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 20. ANOVA Summary Table -- Interpersonal Process Behaviors

	df	Error df	F
Linear Effects			
Within			
Time	2	58	1.741
Between			
Complexity	1	29	1.769
Training	2	29	.457
Two-Way Interactions			
Within			
Time x Complexity	2	58	6.785**
Time x Training	4	58	.639
Between			
Complexity x Training	2	29	.026
Three-Way Interaction			
Within			
Time x Complexity x Training	4	58	2.772*

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 21. **ANOVA Summary Table -- Action Process Behaviors**

	df	Error df	F
Linear Effects			
Within			
Time	2	60	1.24
Between			
Complexity	1	30	.107
Training	2	30	2.298
Two-Way Interactions			
Within			
Time x Complexity	2	60	1.825
Time x Training	4	60	.207
Between			
Complexity x Training	2	30	.769
Three-Way Interaction			
Within			
Time x Complexity x Training	4	60	1.637

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 22. ANOVA Summary Table -- Transition Process Behaviors

	df	Error df	F
Linear Effects			
Within			
Time	2	60	1.574
Between			
Complexity	1	30	.145
Training	2	30	.702
Two-Way Interactions			
Within			
Time x Complexity	2	60	.016
Time x Training	4	60	.663
Between			
Complexity x Training	2	30	.892
Three-Way Interaction			
Within			
Time x Complexity x Training	4	60	.436

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 23. Time x Complexity Interaction

Dependent Variable: MTS BARS interpersonal rating

TIME	COMPLEX	Mean	Std. Deviation	N
1	Low	3.2315	.9005	18
	High	3.1574	.6454	18
2	Low	3.2941	.7961	17
	High	2.9815	.6515	18
3	Low	3.4259	.8805	18
	High	2.7037	.6251	18
Total	Low	3.3176	.8487	53
	High	2.9475	.6562	54

Table 24. Time x Complexity x Training Interaction

Dependent Variable: MTS BARS Interpersonal rating

TRAINING	TIME	COMPLEX	Mean	Std. Deviation	N
Coordination	1	Low	3.7500	1.0891	6
		High	3.1667	.4472	6
	2	Low	3.2667	.9022	5
		High	3.1944	.4878	6
	3	Low	3.5833	1.0737	6
		High	3.0000	.3162	6
Strategy	1	Low	3.0000	.4830	6
		High	3.1111	.9108	6
	2	Low	3.4444	.4792	6
		High	2.9167	.9113	6
	3	Low	3.4444	.6025	6
		High	2.6944	.8460	6
Control	1	Low	2.9444	.9230	6
		High	3.1944	.6184	6
	2	Low	3.1667	1.0488	6
		High	2.8333	.5375	6
	3	Low	3.2500	1.0260	6
		High	2.4167	.5553	6
Total	1	Low	3.2315	.9005	18
		High	3.1574	.6454	18
	2	Low	3.2941	.7961	17
		High	2.9815	.6515	18
	3	Low	3.4259	.8805	18
		High	2.7037	.6251	18

Table 25. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TEAM PROCESS AND ENVIRONMENTAL COMPLEXITY ON MTS TEAM PERFORMANCE

Observations = 108

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 72$
$df_{total} = 107$

Average variance = 2210.476
Total variance = 4408.411

IVs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Interpersonal	-.117	.01		1.93	(1, 68)
Action	.393	.106		20.44**	(1, 68)
Transition	.058	.003		.57	(1, 68)
Complexity	-.146	.02	1.41		(1, 34)
Complexity x Coordination Training	-.464	.014	.95		(1, 30)
Complexity x Strategy Training	.062	0.0	0.0		(1, 30)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 26. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TRANSITION PROCESS BEHAVIORS ON MTS INTERPERSONAL PROCESS

Observations = 107

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 71$
$df_{total} = 106$

Average variance = .532
Total variance = .603

IVs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Transition	.147	.012		16.08**	(1, 70)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 27. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TRANSITION PROCESS AND COORDINATION TRAINING ON MTS ACTION PROCESS

Observations = 108

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 72$
$df_{total} = 107$

Average variance = .292
Total variance = .476

Ivs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Transition	.26	.066		14.62**	(1, 71)
Coordination Training	.228	.05	3.02		(1, 34)
Complexity x Coordination Training	-.542	.02	1.18		(1, 32)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 28. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF STRATEGY TRAINING AND ENVIRONMENTAL COMPLEXITY ON MTS TRANSITION PROCESS

Observations = 108

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 72$
$df_{total} = 107$

Average variance = .351
Total variance = .461

	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Strategy Training	-.129	.017	.78		(1, 34)
Complexity x Strategy Training	.701	.039	1.78		(1, 32)

*indicates p ≤ .05
**indicates p ≤ .01

Table 29. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TEAM PROCESS ON MTS TEAM PERFORMANCE (TRIMMED MODEL)

Observations = 108

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 72$
$df_{total} = 107$

Average variance = 2210.476
Total variance = 4408.411

IVs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Interpersonal	-.117	.004		.76	(1, 68)
Action	.309	.101		19.21**	(1, 68)
Transition	.113	.012		2.05	(1, 68)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 30. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TEAM PROCESS AND ENVIRONMENTAL COMPLEXITY ON MTS TEAM PERFORMANCE (TRAINING SCALE SCORES)

Observations = 108

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 72$
$df_{total} = 107$

Average variance = 2210.476
Total variance = 4408.411

IVs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Interpersonal	-.117	.01		1.93	(1, 68)
Action	.393	.106		20.44**	(1, 68)
Transition	.058	.003		.57	(1, 68)
Complexity	-.146	.02	1.41		(1, 34)
Complexity x Coordination Training	-.169	.001	.07		(1, 30)
Complexity x Strategy Training	.026	0.0	0.0		(1, 30)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 31. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TRANSITION PROCESS BEHAVIORS ON MTS INTERPERSONAL PROCESS (TRAINING SCALE SCORES)

Observations = 107

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 71$
$df_{total} = 106$

Average variance = .532
Total variance = .603

IVs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Transition	.147	.022		16.08**	(1, 70)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 32. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TRANSITION PROCESS AND COORDINATION TRAINING ON MTS ACTION PROCESS (TRAINING SCALE SCORES)

Observations = 108

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 72$
$df_{total} = 107$

Average variance = .292
Total variance = .476

Ivs	ß	R^2 Increment	F Incr Btwn	F Incr W/in	df
Transition	.227	.048		10.07**	(1, 71)
Coordination Training	.279	.073	4.59*		(1, 34)
Complexity x Coordination Training	.166	0.0	0.0		(1, 32)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 33. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF STRATEGY TRAINING AND ENVIRONMENTAL COMPLEXITY ON MTS TRANSITION PROCESS (TRAINING SCALE SCORES)

Observations = 108

Number of teams = 36

$df_{Between}$ = 35
df_{Within} = 72
df_{total} = 107

Average variance = .351
Total variance = .461

	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Strategy Training	-.148	.022	1.01		(1, 34)
Complexity x Strategy Training	.078	.003	.13		(1, 32)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 34. RETEST OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TEAM PROCESS AND ENVIRONMENTAL COMPLEXITY ON MTS TEAM PERFORMANCE (INTERVIEW)

Observations = 108

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 72$
$df_{total} = 107$

Average variance = 2210.476
Total variance = 4408.411

IVs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Interpersonal	-.117	.01		1.91	(1, 68)
Action	.404	.110		21.04**	(1, 68)
Transition	.025	.001		.19	(1, 68)
Complexity	-.148	.021	1.49		(1, 34)
Complexity x Strategy Training	.085	0.0	0.0		(1, 30)
Complexity x Coordination Training	-.458	.014	.95		(1, 30)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 35. RETEST OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TRANSITION PROCESS BEHAVIORS AND ENVIRONMENTAL COMPLEXITY ON MTS INTERPERSONAL PROCESS BEHAVIORS (INTERVIEW)

Observations = 107

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 71$
$df_{total} = 106$

Average variance = .532
Total variance = .603

IVs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Transition	.149	.022		16.08**	(1, 70)
Complexity	.236	.054	2.22		(1, 34)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 36. RETEST OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF TRANSITION PROCESS BEHAVIORS AND COORDINATION TRAINING ON MTS ACTION PROCESS BEHAVIORS (INTERVIEW)

Observations = 108

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 72$
$df_{total} = 107$

Average variance = .292
Total variance = .476

IVs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Transition	.26	.065		14.35**	(1, 71)
Coordination Training	.215	.044	2.63		(1, 34)
Complexity x Coordination Training	-.578	.023	1.35		(1, 32)

*indicates $p \leq .05$
**indicates $p \leq .01$

Table 37. SUMMARY OF REPEATED MEASURES REGRESSION ANALYSIS OF THE EFFECTS OF STRATEGY TRAINING AND ENVIRONMENTAL COMPLEXITY ON MTS TRANSITION PROCESS BEHAVIORS (INTERVIEW)

Observations = 108

Number of teams = 36

$df_{Between} = 35$
$df_{Within} = 72$
$df_{total} = 107$

Average variance = .351
Total variance = .461

IVs	β	R^2 Increment	F Incr Btwn	F Incr W/in	df
Strategy Training	-.121	.015	.64		(1, 34)
Complexity x Strategy Training	.742	.036	1.51		(1, 32)

*indicates p ≤ .05
**indicates p ≤ .01

Table 38. Summary of Results

Proposed Hypotheses:	Supported: Original Model	Supported: Training Scale Scores	Supported: Interview Ratings (Transition)
Hypothesis 1: Higher levels of transition process behaviors will be associated with higher levels of multi-team system (MTS) performance.	YES - mediated	YES - mediated	NO
Hypothesis 2: Higher levels of action process behaviors will be associated with higher levels of MTS performance.	YES	YES	YES
Hypothesis 3: Higher levels of interpersonal process behaviors will be associated with higher levels of MTS performance.	NO	NO	NO
Hypothesis 4: Higher levels of transition process behaviors will result in increased levels of effective team action process behaviors.	YES	YES	YES
Hypothesis 5: Higher levels of transition process behaviors will result in increased levels of effective team interpersonal process behaviors.	YES	YES	YES
Hypothesis 6: Increased levels of environmental complexity will have a direct negative impact on teams' performance in multi-team environments.	NO	NO	NO
Hypothesis 7: Teams receiving strategy training will exhibit more effective transition process behaviors than other teams.	NO	NO	NO
Hypothesis 8: Teams receiving coordination training will exhibit more effective action process behaviors than other teams.	NO	YES	NO
Hypothesis 9: There will be less difference in the performance of teams receiving strategy training versus those that do not (i.e., control) at lower levels of complexity than at higher levels.	NO	NO	NO
Hypothesis 10: There will be less difference in the performance of teams receiving coordination training and those that do not (i.e., control) at lower levels of complexity than at higher levels.	NO	NO	NO
Hypothesis 11: Teams receiving strategy training will perform better in more complex situations than teams in the control condition.	NO	NO	NO
Hypothesis 12: Teams receiving coordination training will perform better in more complex situations than teams in the control condition.	NO	NO	NO
Additional effects identified during analysis:			
- Action process behaviors mediate transition process effects on performance.	YES	YES	NO
- Action process behaviors mediate coordination training effects on team performance.	NO	YES	NO
- Coordination training enhances interpersonal process behaviors.	NO	YES	NO

Appendix B. Analysis of Potential Sample Population Effects

A series of ANOVAs was accomplished to determine if significant differences existed between the two subject populations for any of the four dependent variables examined in this study (i.e., performance, interpersonal process behaviors, action process behaviors, and transition process behaviors). Due to the fact that the coordination training condition was comprised solely of ROTC student participants, it was impossible to compute any effects for any relationships involving training condition and population type.

The results of these analyses are summarized on Tables 1-4 of this appendix. These results indicated that population type had no significant effect on MTS performance. However, as seen in Appendix B, Tables 3 and 4, population type did significantly influence action and transition process behaviors. Furthermore, a significant two-way interaction existed between environmental complexity and population type for transition population behaviors. The ROTC students seemed to do slightly better in these areas than the undergraduate psychology students. However, it was decided that these effects did not require additional controls within the later analyses since the primary dependent variable in the model, i.e. MTS performance, was not affected by population type.

Appendix B, Table 1. ANOVA SUMMARY TABLE -- MTS PERFORMANCE

	df	Error df	F
Linear Effects			
Within			
Time	2	60	.57
Between			
Type	1	30	1.34
Two-Way Interactions			
Within			
Time x Type	2	60	1.69
Between			
Complexity x Type	1	30	.356
Three-Way Interaction			
Within			
Time x Complexity x Type	2	60	2.769

*indicates $p \leq .05$
**indicates $p \leq .01$

Appendix B, Table 2. ANOVA SUMMARY TABLE -- INTERPERSONAL PROCESS BEHAVIORS

	df	Error df	F
Linear Effects			
Within			
Time	2	58	1.27
Between			
Type	1	29	.064
Two-Way Interactions			
Within			
Time x Type	2	58	.048
Between			
Complexity x Type	1	29	.749
Three-Way Interaction			
Within			
Time x Complexity x Type	2	58	1.60

*indicates $p \leq .05$
**indicates $p \leq .01$

Appendix B, Table 3. ANOVA SUMMARY TABLE -- ACTION PROCESS BEHAVIORS

	df	Error df	F
Linear Effects			
Within			
Time	2	60	1.47
Between			
Type	1	30	13.44**
Two-Way Interactions			
Within			
Time x Type	2	60	.02
Between			
Complexity x Type	1	30	.20
Three-Way Interaction			
Within			
Time x Complexity x Type	2	60	1.94

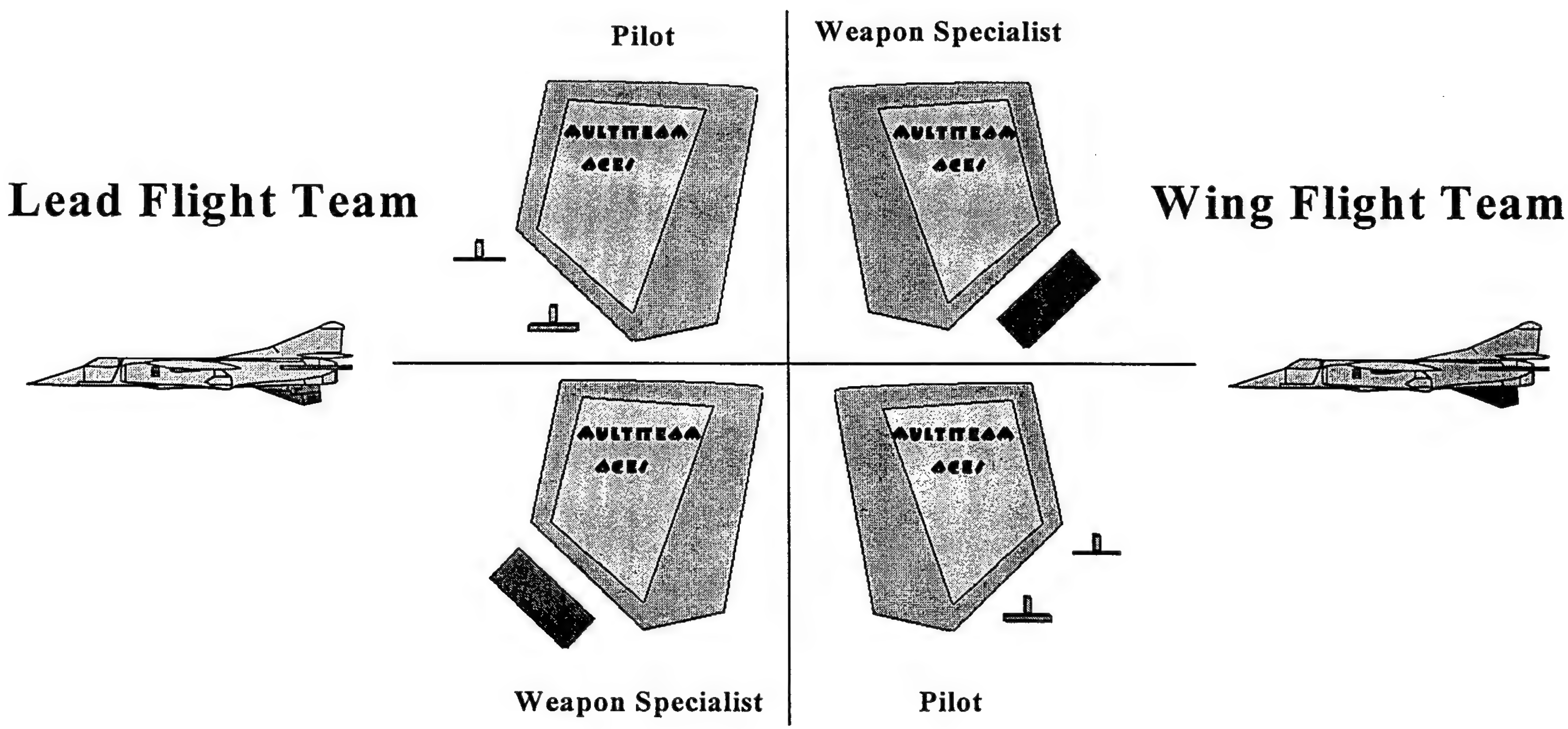
*indicates $p \leq .05$
**indicates $p \leq .01$

Appendix B, Table 4. ANOVA SUMMARY TABLE -- TRANSITION PROCESS BEHAVIORS

	df	Error df	F
Linear Effects			
Within			
Time	2	60	1.61
Between			
Type	1	30	6.25*
Two-Way Interactions			
Within			
Time x Type	2	60	.06
Between			
Complexity x Type	1	30	4.51*
Three-Way Interaction			
Within			
Time x Complexity x Type	2	60	.20

*indicates $p \leq .05$
**indicates $p \leq .01$

Appendix C. MTS Laboratory Layout



Appendix D. Training Protocol

Note: Italicized type is notes to the experimenter. Plain type is what should be told to the participants. It is not necessary to follow the scripted parts word for word although it is important that the participants do receive this information. The important point is that participants attain the competencies listed on the task training competency checklists.

I. In this training segment, you will learn the basics of how to fly the F22 simulator. Some of you may have had previous experience with flight simulators or even with the simulation being used in this study. If you are familiar with this simulation, we ask that you only use those functions demonstrated in the training. Otherwise, the results of this study could be jeopardized.

II. Begin **Navigating a Flight route.**

In this mission you will learn the basic operations of the joystick, throttle, and how to read information on the Heads-up-Display, or HUD. Next, you will learn how to perform the following maneuvers with the joystick: 1) climbing and diving; 2) rolling from side to side; and 3) turning left and right. You will also learn how to speed up and slow down the plane. Then, you will learn how to look around in the cockpit.

A. *Click on "Practice Mission 1" to begin the simulation.*

B. *Pause the game as it begins, and point out the following (use pictures of the HUD to point these out) :*

1. *Point out the roles of the Weapons Specialist and the Pilot:*
   The Pilot is responsible for maneuvering the aircraft, controlling its speed, and firing weapons.
   The Weapons Specialist is responsible for the aircraft's radar settings, choosing the appropriate weapons, releasing chaffs and flares, and communication system.
2. *Altitude Display, right of the HUD's center.*
3. *Speed Display, just left of the HUD's center.*
4. *The Horizon bars.* These are two long "L" shaped bars. When these are in the middle of the screen, the plane is flying level.
5. *The Pitch Ladder.* These are smaller "L" shaped bars above and below the Horizon bar. They have numbers to the left of them. The numbers tell you what angle the plane is pointed up or down.
6. *The HUD mode.* At the top of the HUD display it currently reads "**AA HUD.**" This stands for Air-to-air HUD. In this mode you can obtain information about, target and fire at enemy aircraft. You can switch the HUD mode by pressing "HUD MODE" on the keyboard. Press "HUD MODE" now. Notice that it now reads "**AG HUD.**" This stands for Air-to-ground HUD. In this mode you can target and fire at enemy ground targets. Press "HUD MODE" until you see "**NAV HUD.**" This stands for Navigation HUD. In this mode, you can obtain information about how well you are following your flight plan.
7. *The clock.* There is a clock at the bottom left of the screen. In later missions, you will use this clock to accomplish certain goals within a given amount of time. The weapon specialist will have to take responsibility for watching this clock.

C. *Release pause on the game.* Allow the participants to practice maneuvering the plane.

D. *Demonstrate the following, using a toy plane as visual aid:*

1. *Climbing* – Pull the joystick back. Notice that the pitch ladder moves. Identify the angle you are flying at. Notice the altimeter rising and the speed falling. Pull back until the pitch ladder reads "80" for an eighty degree angle of ascent. Point out that the speed is rapidly falling. *Allow the participants to fly nearly straight up until their*

planes loose momentum and stall. If your plane should stall, you need to point the nose down to gain speed. As the plane tumbles, it will gain speed, and at around 200 knots it will gain maneuverability again. Level the plane off.

2. *Diving* – Now push the joystick forward. Notice the pitch ladder is now displaying negative numbers for a negative angle from level flight. Notice that the altimeter is falling and the speed is rising.
3. Straighten the plane out so that you are flying level.
4. Pull the joystick to the right. Hold it to the right. Notice that the plane is rolling but is still flying in the same direction. Straighten the plane out again. Simply pushing the joystick to the left or right will not allow you to turn the plane.
5. *Turning* - To turn the plane requires two steps. We will first practice a right turn. First, pull the joystick to the right until the plane is on its side or perpendicular to the ground. Now, pull back on the joystick. Straighten the plane and turn to the left.
6. *Speed Control* – To accelerate, push the throttle all the way forward. Notice that the Engine Power display in the bottom right of the HUD now reads "ENG 140%." You are now flying at 140 percent of the engine's capacity, the aircraft's maximum throttle. This is the F22's fastest setting, but flying at 140% for too long could cause you to run out of fuel and crash. Notice that the speed is increasing. Now, pull the throttle all the way back. Notice the Engine Power now reads "ENG 51%." This is the engine's lowest setting. Notice that your air speed is decreasing. At this setting, the aircraft will soon loose momentum and tumble towards the ground. The normal setting is at 100% power. The F-22 performs best when flying at between *400 and 550* knots per hour.
7. *Braking* – You've just seen how to slow the plane down using the throttle, another way to quickly slow the plane down is by using an airbrake. Using your pinky finger, push the maroon button on the bottom side of the joystick that is facing away from you. Notice that when you push it "ABK ON" appears at the bottom right side of the screen. Notice that the plane is slowing down. Now push the button again. Notice that the HUD now reads "ABK OFF."
8. *Looking around* – You can use a switch on the joystick to simulate head movement. You can use this switch to "look around" in the cockpit and out of the plane. Using your thumb, move the round gray knob on the joystick. Notice that its movement parallels that of your virtual head. You can push the red button, next to the gray knob, to snap back to the front view.
9. Now, fly towards the ground. At 2500 feet, level off and fly straight. Attempt to fly as close as you can to the ground. *Make sure they notice the "ground proximity warning" and PULL UP on the HUD.* When you hear this warning, you should pull up quickly to avoid crashing. Notice that you need to anticipate changes in the altitude of the ground.

E. Basic Maneuvering Competencies:

Here, we want to make sure the participants have learned the important task competencies for this mission. The experimenter should ask them to do the following. If the participants cannot do so, show them how and quiz them again later.

1. **Now I would like you to climb to 25,000 feet.**
2. **Now dive to 15,000 feet.**
3. **Accelerate to 550 knots.**
4. **Slow down to 300 knots.**
5. **Look to the left of your plane...and now look straight ahead.**

Then ask them, **"What is your..."**

6. **Altitude.**
7. **Speed.**

Grab the joystick and put the plane at a 30 degree angle.

8. **Are you flying up or down...and at what angle?**
9. ***Stall out their plane and have them recover.***

Now we will build upon the skills that you have just developed and teach you how to: 1) following a flight plan and waypoints; 2) using the navigation HUD to follow a flight plan and; 3) identifying other aircraft.

A. *As the simulation begins, ask participants to push "SHIFT and PILOT AIDS."* This brings up two radar screens. The screen on the bottom left shows your plane in relation to other planes in the sky. The second screen, on the bottom right shows your plane in relation to the flight plan. Notice that on the latter of these, there are lines. This is the path that you are supposed to follow. Also, these lines have circles with numbers on them. These are waypoints. You are supposed to follow waypoints in the order given. For example, you proceed from waypoint two to three and then to four, etc. The pilot is responsible for watching the display on the left. The Weapons Specialist is responsible for watching the display on the right. The W.S. should routinely update the pilot on their relation to the flight route.

B. Make sure you are in the NAV HUD mode.

C. *Release the pause on the game. Instruct the participants to fly towards waypoint two at 20,000 feet. At waypoint two, point out how the waypoint carets on the HUD move and position so that you can fly to waypoint three. Pause the game.* When you fly directly over a waypoint, your computer will automatically switch the HUD settings to the next waypoint. However, in later missions, you may not be able to fly directly over a waypoint due to the need to attack a target or if you are under attack. In these cases, you can manually switch to the next waypoint by pressing ADVANCE WAYPOINT. *Point out how the carets and "WP2" readout in the NAV HUD changes. Also point out how the circle around the next waypoint changes on the right pilot's aid.* If you goof and press W more than once and accidentally advance to the wrong waypoint, you can press "WAYPOINT BACK" to move the waypoint back one. *Have them press WAYPOINT BACK and watch the waypoint indicators.*

D. *Pause the game. Explain EMCOM.*
   1. EMCOM refers to the plane's radar systems. There are five EMCOM levels. One is the stealthiest. It is very hard for enemy's to see you in EMCOM level one. However, it is also harder for you to see enemy's and to lock onto them. EMCOM five allows you to gather the best information concerning enemies near you. However, it is also much easier for enemies to see and to shoot at you.
   2. EMCOM can be changed by pushing "EMCOM" and then a number, 1 through 5, for the desired EMCOM level. *Have them change EMCOM levels. Release pause.*

E. *Have the subjects drop to 2000 feet and fly towards waypoint three at exactly 500 knots. When it looks like the particpants have the hang of it, end the mission.*

F. At waypoint three the game should end.

F. Navigating a Flight Route Competencies.
   1. ***Take the stick and put the participants off course. Turn off their pilot aids and switch the HUD to AG.*** **Fly towards waypoint two.**
   2. ***If the participants did not demonstrate how to do so in finding their way back to waypoint two, ask them to:***
      a. **Increase the range of the pilot aids.**
      b. **Decrease their range.**
      c. **Switch to the Navigation HUD.**
      d. **Advance the waypoint.**
      e. **Move the waypoint back.**
   3. ***If the participants are on course, ask them how they know that.***

4. *Ask them:*
    a. **What is your speed?**
    b. **What is your altitude?**
    c. **What do you look at to find the next waypoint?**
    d. **Change EMCOM to the level where enemies will have the hardest time "seeing" you.**
    e. **Change EMCOM level where you can "see" the most but enemies can also "see" you best.**

IV. Begin **Basic Air-to-Ground.**
In this mission you will learn air-to-ground combat tactics including: 1) how to identify enemy ground targets; 2) how to target enemy ground vehicles; 3) how to fire air-to-ground weapons; and 4) how to identify surface-to-air weapons, or SAMS and the importance of avoiding them.
Here, the subjects will practice blowing up things on the ground. When it appears that they've attained their air-to-ground competencies, have them proceed to waypoint four where they will receive a brief overview of air-to-air tactics.
A. *Click on "Practice Mission 4" to begin the simulation.*
B. Since your objective here is to destroy ground targets, you must be in the AG HUD mode. Switch to this mode by pressing "CHANGE AG WEAPONS" or the "HUD MODE" key until you see "AG HUD" at the top of the HUD.
C. *As the subjects approach the first enemy ground target, pause the game.* There are several types of enemy ground targets. In this mission, you will attack tanks, fuel tanker trucks, and SAM sites. The tanks and fuel trucks are displayed on the HUD as crosses. There are also SAM sites. These are surface to air weapons that fire at aircraft. They are displayed in the HUD as pentagons. These are the only type of ground target that can also fire at you.
D. Notice that we are approaching a ground target that has not been targeted. The dotted lines indicate that this target hasn't been added to our shootlist. Targets that aren't in the shoot list cannot be fired at. Add it to the shoot list by pressing "T," just like the AA targets. Identify the type of ground target we are approaching by looking at the infrared display just below the HUD. Your mission will be to destroy enemy ground targets. *Use pictures of these to show what they look like to the players.* There will also be friendly troops on the ground. *Point out the friendly ground weaponry on the visual aids. Note that friendly M1 tanks look similar to enemy T-80s. M1's have flatter more elongated turrets. Or, if they can't see the difference, tell them to look for HUMVEEs. If HUMVEEs are with the tanks then they are friendly forces.* Do not fire at the friendly forces.
E. Now that the plane is targeted, notice that a circle has appeared around it on the HUD display. When you fire missiles, they will only lock onto this target. If you have more than one target on your screen and you push "ADD TARGET" to target, the computer automatically selects the one closest to you. If you do not want to fire at the target because it may be a jeep, you must push "CYCLE TARGET" to cycle.
F. The distance to the ground target is displayed next to a vertical bar near the bottom right side of the HUD. Next to this bar, the distance is displayed in nautical miles.
G. We want to shoot the ground target, so we have three choices of weapons. *(As you discuss their weapons choices, have them cycle the weapons by pressing backspace so that the appropriate weapon appears on the screen. Point out in the HUD where the weapon's name and number available are displayed.)* The first is CANNONs. This is the same weapon we discussed in the last practice mission. To use CANNONs you must be perfectly lined up with the target and within two miles. These should be used only as

a last resort. Another choice are AGM 88's. These are specially designed to lock onto SAM sites. Our other choice is AGM68. These are heat-seeking missiles. They are lethal within about 10 miles. Unless firing at SAM sites, these should be your first choice of weapons.

H. Select the AGM68. When you are within the optimum range, the words "SHOOT" will appear on the HUD and you will hear "SHOOT SHOOT." To fire the AGM68, pull the trigger on the joystick. After you fire at one target, the computer will automatically select the next closest ground target. You should check your infrared screen every time you fire to make sure that a ground target objective is what is targeted. Every time you fire, the computer will automatically advance to the next target in the shoot list. Sometimes, when a group of tanks are right next to each other, it appears that you are firing at the same target. If you pulled the trigger, heard the missile fire, or saw the missile leave the plane then the target in the infrared display will not be the same that you just fired at.

I. The AGM 88's which are used against SAM launchers and triple A, can be fired the same way with one exception: the higher the level of EMCOM you are in, the farther the distance you can shoot from.

J. An "X" will appear over a ground target after it has been fired at. Do not waste missiles firing at the same target. You only have a limited number of missiles and should be used only for your primary targets.

K. *If they haven't already done so, ask them to fly towards a SAM site. Point out the threat rings of the SAM's radar to the participants. Within these circles, the SAM can "see" you. And if they can see you, they can shoot at you. When a SAM fires a missile at them, demonstrate evasive maneuvering techniques*
   1. *Turning away from the SAM, moving erratically.*
   2. *Launching chaffs and flares.*

L. *Allow participants to practice as needed.*

M. **Basic Air-to-Ground Competencies**
   1. **What weapon is currently selected?**
   2. **How many do you have?**
   3. **Where are the enemy ground targets in relation to you?**
   4. ***Pick one of the ground targets on the HUD and ask them* "What kind of target is that (e.g., a tank, fueltruck, etc.)?" *Participants should use their MFD (or infrared display) to ID the target.***
   5. ***Hit the "C" key a number of times to cycle through the ground targets. Ask them where the primary target is at. They should look for the target with the circle around it on the HUD and pilot aids.***
   6. ***Ask them to pick the appropriate weapon and to fire at the target when ready. They should pick a AGM 88 if it is a SAM site and a AGM 68 if it is anything else. They should wait until they here and see "SHOOT SHOOT" to fire.***
   7. ***After firing, ask them how they know a missile is heading towards the target. (An "X" will appear over the target.)***
   8. ***Tell them to pretend that a missile has been fired at them. Ask them to show you how they would keep the missile from hitting them. (They should turn and launch chaffs and flares.***

N. *When the subjects appear competent on air-to-ground segment, instruct them to fly to waypoint four. At waypoint four, pause the game and explain that they will now receive some basic air-to-air training. This training is just in case they are attacked by an enemy jet and need to fight their way out. However, you should emphasize that their main mission is to attack enemy ground targets and that they should not waste time going after enemy planes.*

O. *To fire at an enemy plane, you must be in the air-to-air HUD mode. Display the AA HUD mode by pressing "CHANGE AA WEAPONS" or the "HUD MODE" key until you see "AA HUD" at the top of the HUD.*

P. *As the subjects approach the first enemy,(it comes up quickly) pause the game.* Notice that an aircraft is approaching that has not been targeted. Add it to the shoot list by pressing "ADD TARGET." Identify the type of plane that is approaching. It is a MIG-21. Any plane that's name begins with SU or MIG is an enemy plane. These planes will attempt to shoot you down. You must then attempt to either avoid the plane or to shoot them down. All other planes should not be considered a threat and should be ignored.

A. Now that the plane is targeted, notice that a circle has appeared around it on the HUD display. When you fire missiles, they will only lock onto this plane.

B. We want to shoot down the targeted plane, so we have two choices of weapons. One is CANNONs. These are basically bullets. In order to hit a plane with the CANNONs, you must be within two miles and be perfectly lined up with the target. Our other choice is AIM9xs. These are heat-seeking missiles. They are lethal within about 10 miles. You can switch between these missiles by pressing the "CHANGE AA WEAPONS" key. Do that now several times. Watch the HUD display to see what weapons you have selected. Look next to the "WEP" display.

C. Select the AIM9x. A heat seeking box will appear on the screen. This box will enclose the circle representing the enemy aircraft on the HUD display when you have "locked on" to the target. When within firing range, a circle will appear in the middle of the HUD. The larger the circle is, the better the chances are of hitting the primary target with an AIM9X. Also, when you are within the optimum range, the words "SHOOT" will appear on the HUD and you will hear "SHOOT SHOOT." To fire the AIM9x, pull the trigger on the joystick.

D. After you fire a missile at a plane, notice that an "X" will appear over the circle. That means that the missile is on its way to the target. Do not fire any additional missiles unless the "X" disappears. If it does, that means that the plane has outmaneuvered the missile. You will have a limited number of missiles in these missions and should not waste them.

E. *Release pause on the game and allow participants to finish the simulation.*

F. **Basic Air-to-Air Competencies**

Ask participants to:

1. **Point out an enemy air target on the HUD and the pilot aids.**
2. **Point out a targeted enemy air target.**
3. **Which target is your primary target?**
4. **Where are you in relation to the target?**
5. **Identify the range of the target.**
6. **Which weapon should be used to fire at the target?**
7. **How many missiles do you have left?**
8. **Are you on course? If not, get back on course.**
9. **What is your speed?**
10. **What is your altitude?**

V. *Participants receive the team training or control condition.*

VI. *Participants see brief video, which serves as an advanced organizer for the multi-team session.*

VII. *Practice Mission 5 (MTS Mission) In-Basket Exercise. Follow In-Basket protocol.*

VIII. Begin **Practice Mission 5.**
In this mission you will fly a mission with another live team. You must work together with this other team, your "wing", to achieve the mission objectives.

A. *Before the mission begins, present participants with a briefing of their mission.* In this mission and all following missions, it is very important that you follow the objectives. Do not get caught up in engagements that are not related to your mission.

B. In this mission you will have a large number of weapons at your disposal. However, in later mission you won't have as many and you will need to be careful not to waste any of your weapons.

C. Explain how the communications switchboxes work.

1. *The participants will work through the mission. During and afterwards, they will be given feedback about where they can improve and what they did well on.*

VIII. Following the training mission, participants will be given measures that will be used to evaluate the training.

Appendix E. Team Training Scoring Criteria

Use the following to score the open-ended questions for the team training manipulation check on page five of the Participant's Package. Use your judgment when comparing actual responses to those listed.

Coordination:

1 point for:

- Checking progress towards objectives
- Monitoring the battlefield and aircraft status
- Backing up teammates
- Coordinating actions

0.5 point for:

Asking: (1) How many objectives have we met already?
(2) What's the most important thing to accomplish right now?
(3) What are we supposed to do next?"
(4) What's going on inside our aircraft?
(5) What's going on outside our plane?
(6) Check with teammate to make sure you understand each other
(7) Monitor teammate's responsibilities
(8) Coach teammate
(9) Time joint actions
(10) Give teammate relevant information
(11) Adjust my behavior to match teammate's behavior

Strategy:

1 point for:

- Identify what your primary and secondary mission objectives are
- Understand and appreciate the larger context or battle in which you are working
- Develop a set of plans and strategies that will help you accomplish your mission
- Change your original plan during the mission, if necessary

0.5 point for:

(1) Knowing how to decide when to abandon your initial and contingency plans
(2) How you will generate and determine a new plan of action
(3) Considering: (1) what flight route or "flight plan" you will fly
(a) what your primary (or most important) targets are
(b) what your secondary (or less important) targets are
(c) what other allied forces are doing in the mission
(d) what enemy activities take place in the mission
(e) what kind of environment will our mission take place in (e.g., terrain)?
(4) Generate alternative plans for accomplishing the mission.

Interpersonal Skills:

1 point for:

- Build members' sense of confidence and motivation
- Maintain positive team atmosphere
- Identify ways to prevent team conflict before it occurs
- Control and reduce team conflict when it occurs."

0.5 point for:

(1) reassure your teammate that your team can accomplish its mission successfully
(2) motivate your teammate regarding accomplishing your mission.
(3) calm-down your teammate if she or he is over-excited
(4) excite your teammate if she or he is too board or quite.
(5) realizing that the conflict has become too severe
(6) employing win-win solutions.
(7) decide what to do when conflict occurs

Appendix F. Team Process Ratings

MISSION ANALYSIS

Definition: Interpretation and evaluation of the team's mission, including identification of the mission's main tasks as well as the operative environmental conditions and team resources available for mission execution.

Examples:
- Gathering appropriate and relevant information
- Understanding the overall MTS mission and the team's contributions to the mission
- Identifying the main tasks and environmental contingencies of the mission
- Prioritizes the mission objectives and required tasks
- Allocating team resources to accomplish each task
- Communicating the mission plan to all team members

Complete skill	5	Team members fully understood their individual/flight team's roles and task responsibilities; they also fully understood the individual or flight team's contribution to the overall mission.
Very much skill	4	
Adequate skill	3	Team members understood their individual/flight team's roles and task responsibilities; but did not understand the individual or flight team's contribution to the overall mission.
Some skill	2	
Hardly any skill	1	Team members did not understand their individual/flight team's roles and task responsibilities; nor did they understand the individual or flight team's contribution to the overall mission. They had no idea what their mission objectives were.

GOAL SPECIFICATION

Definition: Identification and prioritization of goals and subgoals for mission accomplishment.

Examples:
- Developing and assigning overall mission goals for MTS
- Developing and assigning goals for each team in the MTS
- Developing and assigning subgoals that help teams accomplish larger goals

Complete skill	5	Identified and focused on their primary and secondary goals throughout the mission.
Very much skill	4	
Adequate skill	3	Identified and focused on their primary and secondary goals throughout half of the mission.
Some skill	2	
Hardly any skill	1	Displayed no identification of any goals throughout the mission.

STRATEGY FORMULATION & PLANNING

Definition: Formulation of strategies and courses of action for mission accomplishment. This dimension includes generic planning, contingency planning, and reactive strategic adjustment.

Examples:
- Developing a main plan to take out enemy targets without getting killed
- Communicating plans to team members
- Considering factors (e.g., enemy vehicles, friendly casualties) that might alter their mission plan
- Developing an alternative plan or specifically addressing how their mission plan and actions will be adjusted to unexpected events
- Adjusting team actions or responsibilities to adjust to unexpected events (e.g., plane running out of mavericks, enemies are just spotted to the rear of the aircraft).
- Recognizes how unplanned reactions impact remainder of mission plan (e.g., weapons availability, flight route, altitude and airspeed adjustment)

Complete skill	5	Team members (1) developed a primary course of action for mission accomplishment (2) considered a prior alternatives to their primary course of action and developed at least two or three secondary courses of action (3) were able to detect and quickly adapt/coordinate their actions to unexpected situations with appropriate behavior. All team members are aware of and understand how their individual task responsibilities fit into the primary and secondary courses of action.
Very much skill	4	
Adequate skill	3	Team members (1) had some difficulty developing a primary course of action for mission accomplishment (2) briefly considered a prior alternatives to their primary course of action and developed at least one secondary course of action (3) noticed and adapted their individual task responsibilities, but do not coordinate their actions within the MTS. All team members are aware of but may not understand how their individual task responsibilities fit into the primary and secondary courses of action.
Some skill	2	
Hardly any skill	1	Team members (1) were unable to develop a primary course of action for mission accomplishment (2) did not consider a prior alternatives (3) failed to notice unexpected events and situations and were unable to adapt/coordinate their actions. All team members are unaware how their individual task responsibilities fit to accomplish the task at hand.

MONITORING PROGRESS TOWARD GOALS

Definition: Tracking task and goal progress toward mission accomplishment; interpreting system information in terms of what needs to be accomplished for goal attainment, transmitting team goal progress to team members.

Examples:
- Tracking team's (teams') progress on goals and subgoals (e.g., flight routes, targets destroyed, friendly casualties, and time expenditure)
- Reporting team's (teams') progress on goals and subgoals (e.g., flight routes, targets destroyed, friendly casualties, and time expenditure)

Complete skill	5	Maintained awareness of and tracked their primary and secondary goals progress throughout the mission. Understood which individual tasks and flight team responsibilities were necessary for goal attainment.
Very much skill	4	
Adequate skill	3	Maintained awareness of and tracked their primary and secondary goal progress throughout half of the mission for individualized tasks or flight teams. Did not understand how individual tasks and flight team responsibilities fit into goal attainment.
Some skill	2	
Hardly any skill	1	Displayed no awareness or tracking of any goal progress throughout the mission.

SYSTEMS MONITORING

Definition: Tracking team resources and environmental conditions as they relate to mission accomplishment. This dimension includes internal systems monitoring and environmental monitoring.

Examples:
- Tracking team related factors (e.g., weapon availability, speed, fuel, altitude, radar information) and ensure that these systems are operating effectively
- Tracking aspects of the aircraft environment (e.g., terrain shifts, enemy locations and strength, friendly forces)

Complete skill	5	Team members effectively monitor the flight system, each other's individual task responsibilities, and any communication generated within the MTS. They also effectively monitor the external environment, location of enemy targets/threats, friendly and neutral forces, air and ground battles, etc.; keeping in mind the overall MTS mission. Teams understand their individual roles and task responsibilities within this changing environment.
Very much skill	4	
Adequate skill	3	Team members monitor the flight system, and their own individual task responsibilities. They may be some communication generated within the MTS, but they do not attend to it. They also monitor the external environment, location of enemy targets/threats, friendly and neutral forces, air and ground battles, etc. Teams understand their individual roles and task responsibilities within this changing environment.
Some skill	2	
Hardly any skill	1	Team members have no idea how to monitor the flight system, each other's individual task responsibilities, and any communication generated within the MTS. They also fail to monitor the external environment, location of enemy targets/threats, friendly and neutral forces, air and ground battles, etc. Team members have no idea what their individual roles and task responsibilities are within this changing environment.

TEAM MONITORING AND BACKUP BEHAVIOR

Definition: Assisting team members to perform their tasks. Assistance may occur by (a) providing a teammate verbal feedback or coaching, (b) by assisting a teammate behaviorally in carrying out actions, or (c) by assuming and completing a task for a teammate. This dimension includes the provision of feedback and task related support and the seeking of help from teammates when necessary.

Examples:

- Keeping an eye on other teammates to determine if and when they need help
- Helping teammates with their assigned roles by telling them what to do and/or how to do it

Complete skill	5	All team members monitor each other in enacting the appropriate role and task requirements to successfully complete the overall mission.
Very much skill	4	
Adequate skill	3	Team members are more concerned with monitoring whether they themselves are enacting the appropriate role and task requirements to successfully complete the overall mission. Little, if any attentional resources are expended on what other team members are doing.
Some skill	2	
Hardly any skill	1	Team members fail to monitor each other in enacting the appropriate role and task requirements. They really don't even pay attention to what they are doing themselves.

COORDINATION ACTIVITIES

Definition:	Orchestrating the sequence and timing of interdependent actions.
Examples:	- Organizing how and when team members (and teams) will synchronize actions that require the contribution of both pilot and weapons specialist - Organizing how and when team members (and teams) will synchronize actions that require the efforts of more than one team in multi-team situations

Complete skill	5	Maintaining smooth coordination and synchronization of interdependent actions between individual roles and flight teams in accordance with the overall mission.
Very much skill	4	
Adequate skill	3	Maintaining a minimum level of coordination and synchronization of interdependent actions between individual roles in accordance with the overall mission. Team members are not very considered coordinating the MTS.
Some skill	2	
Hardly any skill	1	Complete lack of coordination and synchronization of interdependent actions between individual roles and flight teams. The flight mission is very disorganized and no one knows what is going on.

CONFLICT MANAGEMENT

Definition: Establishing conditions to prevent, control, or guide team conflict before it occurs. Working through task and interpersonal disagreements among team members.

Examples:
- Making statements or offering opinions about task related issues, the way the team functions together, or personal issues, that are likely to affect subsequent team conflict
- Attempting to work through conflict when conflict with the team (or between teams) arises

Complete skill	5	All team members are considerate of differences; they establish a pleasant and cooperative working environment while encouraging team members to present ideas and suggestions regarding the overall mission. Team members are able to constructively discuss problems. If conflict does occur, team members are able to manage and contain the disagreements effectively.
Very much skill	4	
Adequate skill	3	Team members are sometimes considerate of differences; they establish a fair working environment between flight teams. Team members are able to discuss some problems and resolve most types of conflict. Some team members may just "stay out" of any disagreements which arise.
Some skill	2	
Hardly any skill	1	Team members are inconsiderate of differences; they establish an unpleasant and uncooperative working environment regarding the overall mission. Team members argue about problems in a destructive manner and often experience much conflict. They are completely unwilling to discuss the issue at hand and have no clue how to resolve the disagreement.

MOTIVATING AND CONFIDENCE BUILDING

Definition:	Generating and preserving a sense of collective confidence, motivation, and task based cohesion with regard to mission accomplishment.
Examples:	- Motivating each other - Influencing the level of task cohesion of team members with respect to the mission at hand

Complete skill	5	All team members exhibit a strong sense of collective efficacy as well as self efficacy. This attitude creates a positive attitude about the overall mission, and members seek to motivate one another through reinforcement and praise.
Very much skill	4	
Adequate skill	3	Team members exhibit a strong sense of self efficacy, but not much collective. This self-centered attitude allows one to accomplish his/her own task successfully, but there is not much encouragement or motivation between team members.
Some skill	2	
Hardly any skill	1	Team members fail to exhibit any sense of efficacy. This attitude creates a negative attitude about the overall mission, since there is a complete lack of encouragement or motivation between team members.

AFFECT MANAGEMENT

Definition: Regulating member emotions during mission accomplishment, including (but not limited to) social cohesion, frustration, and excitement.

Examples: - Influencing the positive and negative emotions of other members

Complete skill	5	While carrying out the mission objectives, team members effectively extinguished negative emotions and enhanced positive emotions. They were able to regulate and maintain a solid sense of emotional stability within the larger team.
Very much skill	4	
Adequate skill	3	While carrying out the mission objectives, team members extinguished their own negative emotions and retain some positive emotions. They were able to regulate and maintain a moderate level of emotional stability within their flight team, but not so much the larger team..
Some skill	2	
Hardly any skill	1	While carrying out the mission objectives, team members failed to extinguish negative emotions and failed to enhance positive emotions. They were unable to regulate and maintain any sense of emotional stability within their flight team or the larger team.

Appendix G. SME In-Basket Q-Sort

Mission: Canyon Sweep	Important and essential	Helpful, but not essential	Not relevant to mission plan
Sitrep 01	X		
Sitrep 02	X		
Sitrep 03		X	
Sitrep 04			X
Sitrep 05			X
Intel 01	X		
Intel 02			X
Intel 03			X
Intel 04		X	
Intel 05	X		

Mission: River Run	Important and essential	Helpful, but not essential	Not relevant to mission plan
Sitrep 01	X		
Sitrep 02	X		
Sitrep 03			X
Sitrep 04			X
Sitrep 05		X	
Intel 01	X		
Intel 02			X
Intel 03	X		
Intel 04			X
Intel 05		X	

Mission: Ridge Jumper	Important and essential	Helpful, but not essential	Not relevant to mission plan
Sitrep 01			X
Sitrep 02	X		
Sitrep 03		X	
Sitrep 04	X		
Sitrep 05			X
Intel 01			X
Intel 02		X	
Intel 03	X		
Intel 04			X
Intel 05	X		

Appendix H. MTS Weapons Options and SME Rankings

Each aircraft will be loaded with:

- 1760 Cannon rounds (multipurpose) – optimal range = 2NM
- Two (2) AIM-9M (air-to-air) missiles – optimal range = 10NM

PLUS one of the following options:

Option 1:

6 MAVERICKS (air-to-ground, hard targets) missiles – optimal range = 10NM
6 HARMS (high-speed anti-radiation missiles) – optimal range = 15NM

Option 2:
8 MAVERICKS (air-to-ground, hard targets) missiles – optimal range = 10NM
4 HARMS (high-speed anti-radiation missiles) – optimal range = 15NM

Option 3:
4 MAVERICKS (air-to-ground, hard targets) missiles – optimal range = 10NM
8 HARMS (high-speed anti-radiation missiles) – optimal range = 15NM

SME Rankings:

Best Option = 2 points; Next Best = 1 point; Least Effective = 0

	Canyon Sweep	Ridge Jumper	River Run
Option 01	1	1	2
Option 02	0	2	1
Option 03	2	0	1

Appendix I. Post Mission Planning Interview

A. Given that your mission brief specifies exactly what goals and objectives are required of your team, do you have any questions about them?

B. What, in your team's estimation, were the most important pieces of information that you received? Why were they the most important pieces of information for your planning?

C. From the information that you were provided, what else is going on in this mission that might relate to your assignments? How is that related to your mission?

D. How do you plan on achieving the objectives you've identified for this mission? What exactly will the lead and wing aircraft be doing? Do they have any different responsibilities? If so, what?

E. What could go wrong with your plans? It that happens, what will you do? When will you decide whether to carry out that action(s) (i.e., what are your decision points)?

F. Finally, tell me which weapons load you selected for this mission. Why that one?

Appendix J. Interview Process Ratings

MISSION ANALYSIS

Definition: Interpretation and evaluation of the team's mission, including identification of the mission's main tasks as well as the operative environmental conditions and team resources available for mission execution.

Examples:
- Gathering appropriate and relevant information
- Understanding the overall MTS mission and the team's contributions to the mission
- Identifying the main tasks and environmental contingencies of the mission
- Prioritizes the mission objectives and required tasks
- Allocating team resources to accomplish each task
- Communicating the mission plan to all team members

Complete skill	5	Demonstrates a complete understanding of the team's mission, goals, and resources beyond that clearly specified in the mission briefing; Accurately summarizes the team's relationship to other operations and agents in the task environment, as well as identifying how these operations and agents impact the team's assigned mission and strategy.
Very much skill	4	
Adequate skill	3	Demonstrates a general understanding of the team's mission, goals, and resources beyond that clearly specified in the mission briefing; Recognizes that the team's actions may affect other operations and agents in the task environment, as well as identifying how many of these operations and agents impact the team's assigned mission and strategy.
Some skill	2	
Hardly any skill	1	Demonstrates a complete lack of understanding of the team's mission, goals, and resources beyond that clearly specified in the mission briefing; Fails to recognize any relationship between the team's actions and other operations and agents in the task environment; Fails to perceive how these operations and agents may impact the team's assigned mission and strategy.

GOAL SPECIFICATION

Definition: Identification and prioritization of goals and subgoals for mission accomplishment.

Examples:
- Developing and assigning overall mission goals for MTS
- Developing and assigning goals for each team in the MTS
- Developing and assigning subgoals that help teams accomplish larger goals

Level	Score	Behavioral anchor
Complete skill	5	Demonstrates a complete understanding of assigned mission goals, including clearly differentiating between and prioritizing both primary and secondary goals and recognizing how resources should be best allocated to achieve them; If required by the team's mission plan, clearly identifies the primary and secondary goals assigned to each aircraft.
Very much skill	4	
Adequate skill	3	Acknowledged the primary and secondary goals specified in the mission briefing; Recognized the differences between the two types of goals and described how the goals would be prioritized during the mission; Generally identified the goals assigned to the MTS and to each individual aircraft, as required by the team's mission plan; Demonstrated a general understanding of the relationship between weapons selection and assigned goals.
Some skill	2	
Hardly any skill	1	Failed to differentiate between or prioritize any primary and secondary goals; Failed to identify any relationship between the weapons selected and the assigned mission goals.

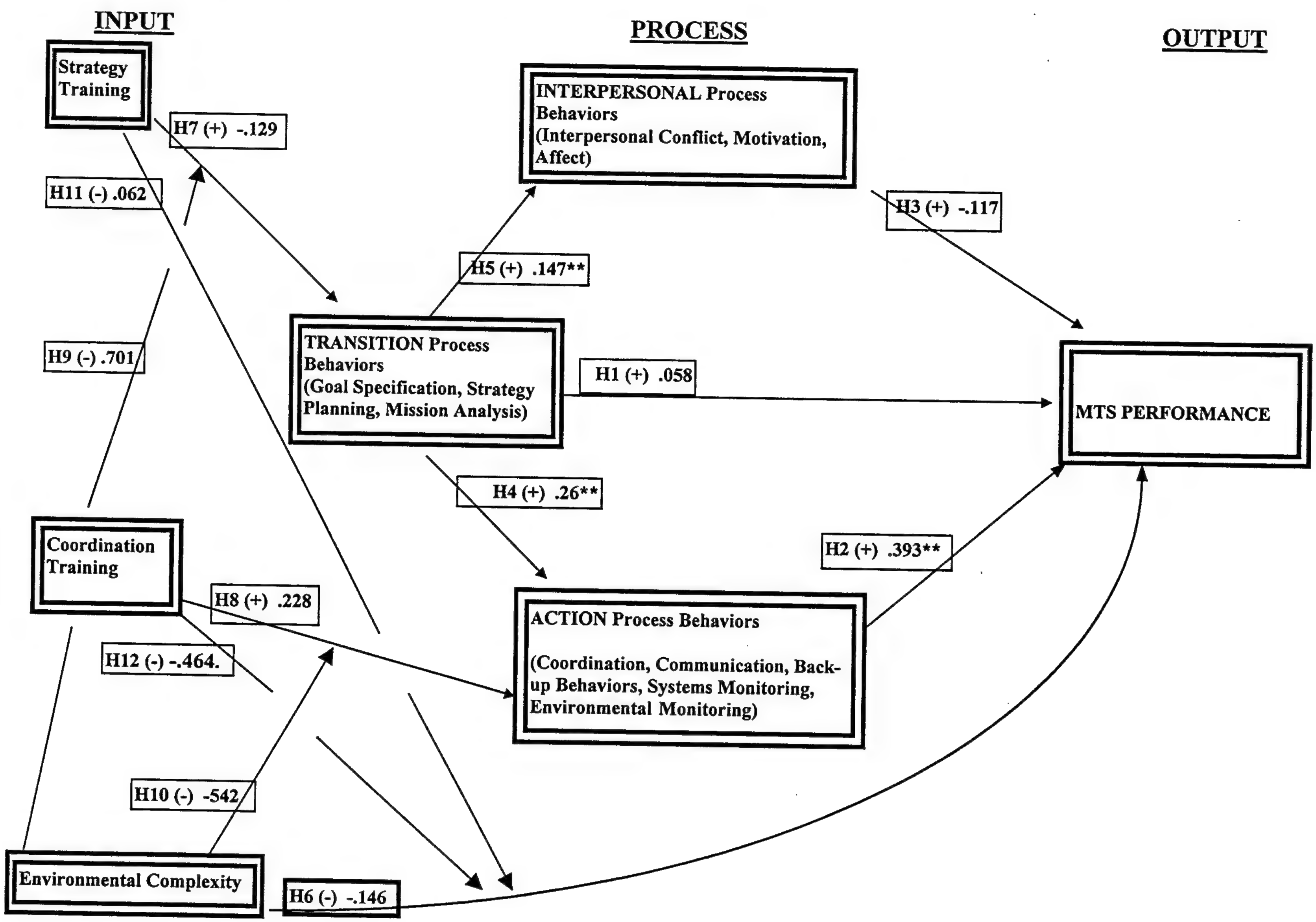
STRATEGY FORMULATION & PLANNING

Definition: Formulation of strategies and courses of action for mission accomplishment. This dimension includes generic planning, contingency planning, and reactive strategic adjustment.

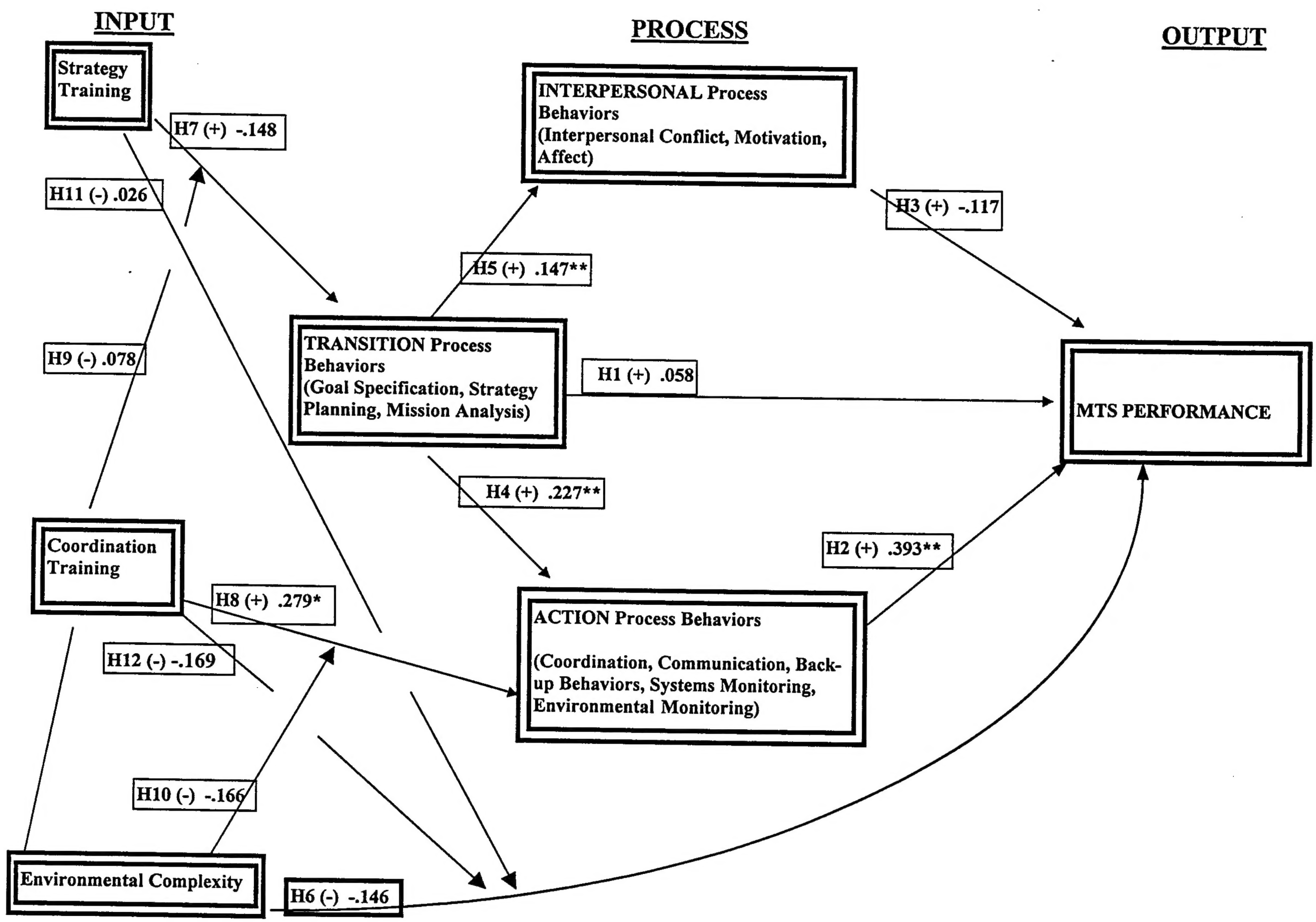
Examples:
- Developing a main plan to take out enemy targets without getting killed
- Communicating plans to team members
- Considering factors (e.g., enemy vehicles, friendly casualties) that might alter their mission plan
- Developing an alternative plan or specifically addressing how their mission plan and actions will be adjusted to unexpected events
- Adjusting team actions or responsibilities to adjust to unexpected events (e.g., plane running out of mavericks, enemies are just spotted to the rear of the aircraft).
- Recognizes how unplanned reactions impact remainder of mission plan (e.g., weapons availability, flight route, altitude and airspeed adjustment)

Skill level	Rating	Behavioral anchor
Complete skill	5	Clearly described a primary course of action to achieve mission goals; Summarized significant events that could adversely impact the team's mission plan; Provided concise courses of action to minimize the impact of these events on team goals; Identified the circumstances under which contingency plans would be implemented or previously conceived actions and responsibilities would be reconsidered and adjusted.
Very much skill	4	
Adequate skill	3	Generally described a primary course of action to achieve mission goals; Briefly identified alternatives to the primary course of action; Briefly described what events or circumstances would cause the primary plan to be adjusted or abandoned for other options; Recognized the need to adjust aircraft responsibilities in the event preplanned courses of action were abandoned.
Some skill	2	
Hardly any skill	1	Failed to describe a coherent course of action for mission accomplishment; Did not identify any significant events that could adversely impact their actions nor any alternatives to preplanned actions; Failed to consider the need to adjust mission responsibilities between the two aircraft due to mission events.

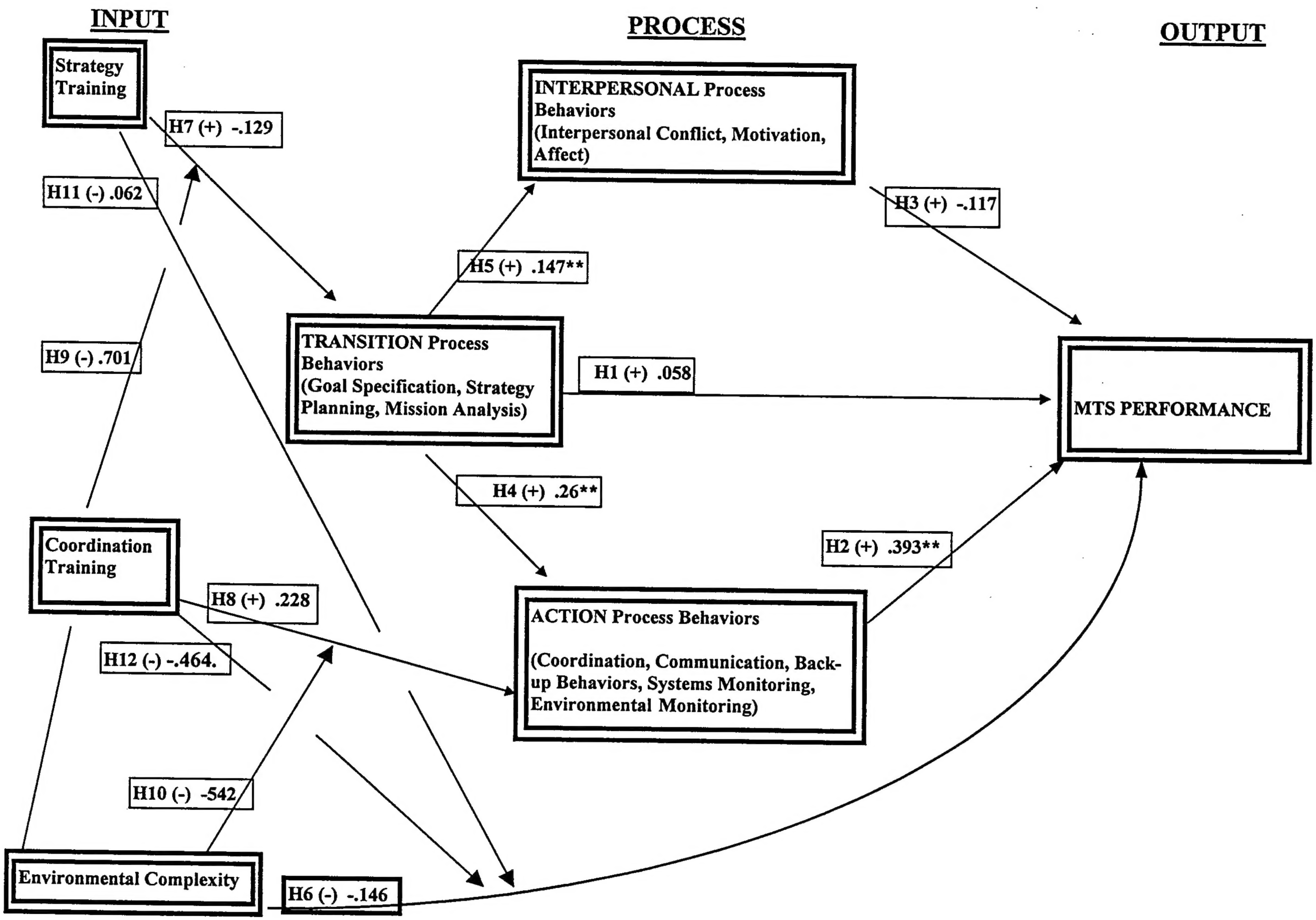
Appendix K. TEST OF HYPOTHESIZED MTS MODEL



Appendix L. TEST OF HYPOTHESIZED MTS MODEL (TRAINING SCALE SCORES)



Appendix M. RETEST OF HYPOTHESIZED MTS MODEL (INTERVIEW)



Appendix N. Human Subjects Approval

PENNSTATE

Vice President for Research
Office for Regulatory Compliance

The Pennsylvania State University
212 Kern Graduate Building
University Park, PA 16802-3301

(814) 865-1775
Fax: (814) 863-8699
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Date: June 1, 1998

From: Karen J. English, Research Compliance Coordinator

Karen J. English

To: Marshell G. Cobb

Subject: Proposal for Use of Human Subjects in Research - Exemption (#980559-00)

Approval Expiration Date: June 1, 1999

"The Impact of Environment Complexity and Ambiguity on AWACS Crew Performance in Simulated Combat Scenarios"

Your proposal for use of human subjects in your research has been reviewed and approved for a one-year period. Subjects in your research are at minimal risk.

By accepting this decision you agree to notify this office of (1) any additions or changes in procedures for your study that modify the subjects' risks in any way and (2) any events that affect the safety or well-being of subjects.

The University appreciates your efforts to conduct research in compliance with the federal regulations that have been established to ensure the protection of human subjects.

KJE/dll

cc: L. S. Liben
R. E. Lombra

Vita

MARSHELL G. COBB (Glenn)
Lieutenant Colonel, USAF
PhD, Industrial and Organizational Psychology

Education:

Civilian: MS; Psychology (area: Industrial Organizational Psychology); Penn State University, PA (1998)

MA; Psychology, Counseling and Guidance (emphasis: Agency Counseling); University of Northern Colorado, Greeley, CO (1982)

BA; Psychology, University of North Carolina, Chapel Hill, NC (1979)

Professional Military Education:

1996 Air War College (Seminar; Outstanding Graduate)
1996 Air Command and Staff College (Residence-Faculty)
1986 Air Command and Staff College (Correspondence)
1984 Marine Command and Staff College (Correspondence)
1983 Squadron Officer School (Residence)

Significant Military Awards and Decorations:

Meritorious Service Medal (2 Oak Leaf Clusters (OLC))
Air Force Commendation Medal (1OLC)

Teaching Experience:

- Director, Training Sciences Division, 4315th Combat Crew Training Squadron, Vandenberg AFB CA
- Assistant Professor, Military Studies Division, USAF Academy, CO
- Training Director, Technical Military Plans Division, HQ USAF, Washington DC
- Assistant Course Director, Air Campaign and Studies, Air Command and Staff College, Maxwell AFB AL

Research Publications/Presentations:

- Presented paper based on preliminary results of Master's thesis research at the NATO Research and Technology Agency's (RTO) Human Factors & Medicine Panel Symposium in Edinburgh, Scotland (UK). Final paper published in proceedings of the symposium. Title of presentation/paper: The Impact of Environment Complexity and Ambiguity on AWACS Crew Performance in Simulated Combat Scenarios.

- Reviewed and approved submissions for presentation at the 1998 and 1999 Annual Meetings of the Academy of Management, History Division.

- Presented paper critically analyzing the citiques of the famous Hawthorne Experiments, 1927-1932, to the Academy of Management, History Division, during the 1997 Academy of Management Annual Meetings in Boston.